Testimony before the Alaska Department of Natural Resources on applications to reserve water in the Chuitna River watershed in Upper Cook Inlet
August 21, 2015

I. Overview

Thank you. My name’s Bob Shavelson and I’m the Executive Director of Cook Inletkeeper, a nonprofit organization founded twenty years ago that works to protect clean water, healthy salmon and a vibrant democracy in Alaska. We have been focused on the Chuitna coal strip mine since around 2004 when the project proponents dusted off their old plans and started another run at exporting coal from the Beluga coalfields in Upper Cook Inlet to Asian markets.

Today I will talk about several topics to show the proposed reservations of water in middle Creek are in the public interest. First I will review studies on international coal markets and pricing structures to show why the Chuitna coal strip mine is not financially viable, and therefore, will not occur within a “reasonable time” to affect alternate uses of the water. Next, I will provide information showing that DNR under-valued Middle Creek and the surrounding Chuitna watershed, and that the proposed reservations will have positive benefits to the applicant and on economic activity, fish and game resources, recreational opportunities, and public health. Finally, I will discuss our permitting process, including salmon stream restoration and how a grant of the instream flow applications does not derail state and federal permitting processes to harm other persons. In conclusion, I will make the case why Commissioner Myers and the Walker Administration have a legal, moral and scientific duty to grant the requested instream flow applications.

II. The Proposed Reservations of Water Will Not Preclude or Hinder Other Alternate Uses of the Water within in a “Reasonable Time” Because the Chuitna Coal Strip Mine Is Not Financially Viable for the Foreseeable Future

The Chuitna coal project dates back more than 40 years, when the original leases were let in the 1970’s. Throughout this time, coal markets have fluctuated, with prices for Pacific Basin coal peaking in early 2011. Yet over all this time, PacRim Coal – and its predecessor - moved slowly; they refused to conduct studies state and federal agencies said were necessary, they never hired sufficient staff to make a real play on the project, and they limped their way through the permitting process. Now, in the past 4 years, with substantial shale gas coming online and climate change considerations affecting market forces, coal prices have plunged

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1 I have been the Executive Director at Cook Inletkeeper since February 1996, and I hold degrees in Biology & Chemistry (B.A., Boston University, 1986) and Law (J.D., University of Oregon, 1993).
2 See AS 46.15.080(b)(5).
3 See id. at (b)(1)-(4), (8).
4 See id. at (b)

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roughly 70% and the market adjustments we’re seeing now appear long term according to most market analysts. As one analyst put it “It’s kind of the ultimate irony that market forces, and not the [Obama] administration or environmentalists, have displaced coal.”

To follow on that, we asked Tom Sanzillo with the Institute for Energy Economics and Financial Analysis to provide a market assessment for Chuitna coal, to get a better sense if this is a real project. Mr. Sanzillo previously managed a $156 billion dollar globally invested public pension fund for the state of New York, and he’s an expert on the U.S. coal industry and international coal markets.

Mr. Sanzillo’s analysis is sobering. He found that global coal prices are collapsing and the market is oversupplied; that leading coal analysts see no market signals for new coal mine development and they project severe retrenchment in the global thermal coal market; and that Chuitna coal would face stiff competition from existing U.S. and Pacific Basin coal producers, including the Usibelli Coal Mine in Healy. In conclusion, Mr. Sanzillo found that “The Chuitna coal project would serve little purpose in this shrinking market over the next several decades. There is no need for the mine and no price structure to support it.”

PacRim, however, states that its coal is somehow immune from these market forces because of its “low sulfur” content, which produces less sulfur oxide (SOx) emissions than other coals and is presumably more desirable. That’s the line PacRim told an industry support group in January 2015.

Mr. Sanzillo’s analysis, however, lays bare these claims. Mr. Sanzillo compared the sulfur levels in Chuitna coal to those in other domestic and international coals, and finds:

“[T]he coal from the proposed Chuitna mine has no inherent competitive advantage over other coal products currently competing in the global marketplace. Chuitna coal contains average levels of sulfur for a low-sulfur product. Chuitna coal contains a low heat value. Companies that produce similar coal, with similar sulfur levels and better heating values, are having difficulty in today’s marketplace, and coal with similar sulfur levels and similar heat levels to Chuitna coal has no export potential for the foreseeable future... Global coal markets are oversupplied and there is no evidence that an Alaskan mine with no

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6 Id. ((quoting Jorge Beristain, head of Americas metals and mining equity research for Deutsche Bank).
product advantage would succeed as a new entrant in the global thermal market place.” 9

I encourage the State to carefully review Mr. Sanzillo’s analysis, because it clearly shows Chuitna coal sulfur levels are comparable to those found in the Powder River Basin, and that established companies in the Powder River Basin, with established Pacific basin buyers – companies such as Alpha Natural Resources, Arch Coal and Peabody Energy - are all dramatically losing value as their exports disappear.10 And as mentioned previously, these market adjustments – according to market analysts and coal company executives alike – appear permanent for the foreseeable future.

But we don’t have to look to the Powder River Basin or to Pacific Basin producers to know there’s been a regime shift in coal markets. In Alaska, the state’s only operating coal mine – the Usibelli Coal Mine - has seen a 57% drop in exports between 2011 and 2014, and a workforce reduction of 15%. According to a news story published just last week, Usibelli’s Vice President of External Affairs “expect[s] to continue to see softening in the export market...”11 And it should be noted, Usibelli produces similar low sulfur, low BTU coal as that found at Chuitna, and Chuitna coal would compete directly with it.

The writing is all over the wall – coal is a dying commodity, and it makes no sense to hold out the grandiose specter of jobs and revenues when the fact remains Chuitna coal is unmarketable at any foreseeable price structure over a reasonable timeframe. Jeff Jessee, the Executive Director of the Alaska Mental Health Trust, recognized the tenuous position of coal in the global marketplace just after coal prices peaked in 2011. During a meeting of the Board of Directors of the Alaska Mental Health Trust in May 2012, Mr. Jessee said:

"...you know there are people that, for whom the concern is the fish, and with Chickaloon and Chuitna we’re going to have a very good story to tell about that. There are however a big group in that negative who are against coal because of the global warming issues and the carbon emissions issues. That's the one issue we can't do anything about other than sell our coal before the environment becomes so negative towards that that it's no longer an economic resource, like asbestos. Now is not a good time to invest in asbestos, but there was a time when asbestos was a good, a good resource to own. And we don't want to be in that position with coal...”12

While I won’t get into the moral dimensions of whether coal should be a marketable commodity – including issues such as climate change, ocean acidification, increased asthma

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10 Id. at p.3.
12 Jeff Jessee, Executive Director, Alaska Mental Health Trust, Board of Directors Meeting, May 10, 2012.
deaths and the myriad problems we know are linked to coal - it’s clear coal is now no longer a good investment choice either.

But it would be hard to understand that if you listened to the chorus of objections from the corporate world, which have all touted the considerable jobs and sizable revenues the Chuitna strip mine will generate. Yet there’s only one problem. They offer no proof to back up their claims. None.

PacRim Coal is a privately held corporation, and as a result, it has chosen not to divulge to the public – or to our government agencies to our knowledge – any type of legitimate business plan that would support its promises of jobs and revenues for the State. As Mr. Sanzillo writes:

“PacRim is asking the State of Alaska to make an economic and financial judgment on the proposed mine, even though the company has not set forth its current, updated business assumptions regarding the mine in the form of a coherent business plan. A business plan would contain at minimum the cost of production of coal at Chuitna, costs of capital, projected revenues based on an estimated market price (and presumably some specific market), an estimate of operating margins and a general debt/equity plan. None of this information is publicly available.”

As discussed previously, the definition of public interest found in Alaska Statutes requires DNR to consider “the effect of loss of alternate uses of water that might be made within a reasonable time if not precluded or hindered by the proposed appropriation.” All available information tells us the proposed Chuitna coal strip mine is a non-starter – there are simply no current or foreseeable markets for the coal, and for whatever markets do or will exist, PacRim is in no position to compete with companies already producing for and supplying these markets.

And finally, it should be noted, PacRim Coal has never operated a coal mine before. Never. Of course it may simply intend to flip its permits if it gets them to a willing buyer – presumably some Asian national corporation. But the fact remains, there’s no reasonable timeframe to expect PacRim Coal or any successor in interest to operate a coal strip mine at Chuitna.

III. The Proposed Water Reservations Will Have Positive Benefits to the Applicant, and on Economic Activity, Fish and Game Resources, Recreational Opportunities, and Public Health in the Middle Creek & Chuitna Watersheds and in Upper Cook Inlet

When making a public interest determination associated with the proposed water reservations, the State must consider a variety of factors found in Alaska Statutes, including the benefit to the applicant resulting from the proposed reservation; the effect of the economic activity; the effect on fish and game resources and public recreational opportunities; the effect on public health; and the effect on access to navigable or public water."

13 Sanzillo, Aug. 19, at p.3.
14 AS 46.15.080(b)(5) (emphasis added).
15 AS 46.15.080(b)(1)-(4), (8).
PacRim Coal and its corporate supporters would have the State believe the only benefits that flow from our water, salmon and wildlife resources are those which can be valued in market transactions. Yet as Alaskans, we recognize that while the value of our natural resources includes a market component, there are also a wide range of economic benefits associated with non-market goods and services - for example, the inherent value of intact watersheds, the economic value of subsistence and recreation uses, and values Alaskans place on the sustainability of our wild salmon runs.

Recognizing the need to understand a broader set of values and benefits – including both quantifiable and non-quantifiable assets – Cook Inletkeeper engaged economist John Talberth to conduct a net public benefits study for the Chuitna coal project.16 Dr. Talberth is the President and Senior Economist at the Center for Sustainable Economy, and he is an expert in non-market valuation, benefit-cost analysis, and sustainability indicators.

Dr. Talberth reviewed the Chuitna watershed and the proposed Chuitna strip mine through a net public benefits analysis, which calculates the overall long-term value of a project’s outputs and positive effects (i.e., benefits) minus its associated inputs and negative effects (i.e., costs) using both quantitative and qualitative criteria.

Dr. Talberth reviewed the national and regional economic development costs and benefits for the Chuitna coal mine – including everything from jobs, income, royalties, rents and fees, to capital and operating costs for the project, impacts to salmon and relevant fisheries, carbon emissions damages and ecosystem services reductions. And while I will not go into all the details of the report, Dr. Talberth concluded the costs of the proposed Chuitna strip mine – based on various conservative coal pricing assumptions - would exceed its benefits by a factor of 3 to 6 times. In other words, if we actually recognize the true and irreplaceable value that our air, water, wetlands, streams and fish and wildlife provide us, the Chuitna project does not pencil out.

To bring this work into the realm of the water reservation applications before us, Dr. Talberth conducted another review, specifically looking at the benefits attached to maintaining adequate flows in Middle Creek, including sport, commercial, personal use and subsistence fishing and hunting, and a variety of ecosystem services supported by a free-flowing Middle Creek.17 Again, without getting into the report’s details, Dr. Talberth concluded:

“...In making a public interest determination associated with Chuitna Citizens Council’s application to reserve instream flow in Middle Creek (Stream 2003) ADNR has not ensured that all significant costs and benefits are considered. In this case, the cursory assessment of just one small type of benefit – the market

16 John Talberth, PhD. & Evan Branosky, Center for Sustainable Economy, Net Public Benefits of the Chuitna Coal Project, June 2011.
value of coho – represents a small amount compared to the vast ecosystem service values that the 9,126-acre Middle Creek watershed generates for Alaskans on an annual basis. These ecosystem service values include those associated with a wide range of direct uses such as hunting, fishing, and subsistence foods, as well as passive use values for maintaining Alaska’s pristine watersheds. Together, they are likely to generate between $55.4 million to $134.2 million in value each year. ADNR has, at its disposal, all of the methods and sources of information needed to produce credible estimates of ecosystem service benefits for the Middle Creek watershed ....”18

Importantly, the values of water reservations in the Middle Creek watershed cannot be limited simply to that one watershed, but they must expand into the Chuitna watershed and Upper Cook Inlet, because these areas are hydrologically connected, and waters flowing through Middle Creek plainly support physical, chemical and biological functions and values downstream.

That’s why DNR must consider what’s known as the portfolio effect. Ground-breaking, peer reviewed science published in 2010 shows that salmon populations behave similar to investment portfolios – that is, they require diversity to weather the ups and downs of good times and bad.19 With salmon, this means they require genetic diversity to counter the broad variations brought about by ever-changing aquatic conditions, to promote the resilience and sustainability salmon need over time. If we view the Upper Cook Inlet ecosystem as a tightly intertwined fabric, then removing vital threads – such as the flow and unique characteristics of Middle Creek and the genetic diversity of the fish it supports – then eventually the entire ecological fabric begins to unravel as the system becomes more vulnerable to regular and irregular variations. Importantly, this phenomenon does not simply manifest in salmon, but in every other species and system in which salmon play a role.

For example, salmon are a vital food source for the Endangered Cook Inlet Beluga whale, whose critical habitat lies at the mouth of the Chuitna River. Upper Cook Inlet supports important economic activities, including oil and gas exploration and production. Increased pressures on Beluga whale prey availability therefore increase the risks around the permits and authorizations needed to conduct business in Cook Inlet, including for such projects as the proposed LNG pipeline and export facility.

As a result, DNR must consider a broader set of values for the reservation of water in Middle Creek, including those associated with activities in Cook Inlet. In 2009, Inletkeeper commissioned experts at ECONorthwest to conduct an economic analysis of the Chuitna watershed and Cook Inlet. The study found that sport fishing for all species was responsible for an estimated $828 million in economic output, $279 million in local income, and more than 8000 jobs in 2007. Additionally, commercial salmon fishing alone had a total economic impact

18 Id. at 17.
of nearly $100 million and employed over 1000 in 2007. And finally, local subsistence harvests for 2005-2006 averaged 217 lbs/person in Tyonek, and 204 lbs/person in Beluga.

It’s important to note that when PacRim and others tout the unsupported economic benefits they claim will flow from the Chuitna strip mine, they are referring to the entire Phase 1 of the proposed project, and not simply to the value associated with the coal underlying Middle Creek. And if DNR embraces PacRim’s rationale for putting a market value on the entire Phase 1 of the mine in the decision whether to grant the Middle Creek reservation, then it must also include in the value of Middle Creek the market and nonmarket values associated with all other streams, creaks and wetlands, among other things, within Logical Mining Unit 1, the entire Chuitna watersed, and into Upper Cook Inlet. PacRim cannot have it both ways.

Thus, by every measure, the proposed instream flow reservations satisfy the public interest test; they will benefit the applicant by supporting healthy fish and wildlife populations, they will result in net positive economic activity by supporting sport, commercial, personal use and subsistence hunting and fisheries; they will benefit fish and game resources by maintaining the functions and values these resources need to thrive; they will support public recreational opportunities by leaving Middle Creek and the Chuitna River in a free-flowing state; they will enhance public health by supporting a wealth of ecosystem services that produce clean water and air; and they will preserve access to our public waters by ensuring they are available for future generations.

IV. Alaska’s Permitting Process, Salmon Stream Restoration & Why Instream Flow Reservations on Middle Creek Will Cause No Harm

Another factor in the public interest determination is whether the reservation of water will cause harm to any person. But granting the instream flow reservations for Middle Creek will not harm anyone – not even a so-called corporate person such as PacRim. While PacRim and its corporate supporters argue the reservations of water will derail ongoing state and federal permitting processes, they are intentionally or unintentionally misconstruing the law, because Alaska Statutes clearly allow the State to modify or revoke the water reservations at a later date. To the contrary, as discussed above, the reservation of water in Middle Creek will confer only benefits on Alaska as a whole.

Another argument posed by the corporations is that it’s bad public policy to allow everyday Alaskans to hold instream flow reservations. Yet the Alaska Constitution clearly reserves our water and fish resources to all Alaskans for common use, so it actually makes perfect sense for Alaska residents to hold these rights. This is especially true when we realize that private corporations – and frequently corporations situated in other states – hold water rights and obtain temporary water use permits which exclude everyday Alaskans from using the same water.

20 AS 46.15.080(b)(6)
21 AS 46.15.145(f).
22 Alaska Constitution, Art. 8, Sec. 3.
So, we do not believe this is an “either/or” proposition, and that granting the Middle Creek reservations in any way hampers the permitting process from moving forward. But even if we do embrace the notion that the State must decide whether this is a “water for salmon or water for coal” decision, it must come down firmly on the side of protecting wild Alaska salmon.

Despite the fact PacRim and its predecessor have had over 40 years to accurately characterize the proposed mine area, they clearly have failed to conduct sufficient analyses to understand the salmon and other resources that would be destroyed by a large coal strip mine.

For example, in July 2014, ADFG conducted field surveys which found PacRim contractors had wrongly identified fish species in the Middle Creek watershed, concluding that “the amount of anadromous fish habitat in the area has been under documented. Further fish investigations are needed to fully document the amount of anadromous fish habitat potentially impacted by proposed mining plans, including proposed alteration of functioning fish habitat for mitigation purposes.”23 And this is after more than 40 years of work to develop a coal strip mine.

Additionally, our top federal resource protection agencies have found PacRim’s plans severely lacking. The U.S. Fish & Wildlife Service, for example, wrote in 2007 that “the proposed project will result in significant adverse impacts to fish populations and habitat, and the majority of these impacts cannot be avoided or minimized due to the inherent nature of coal strip mining.”24 USFWS went on to document a laundry list of data gaps where PacRim could not characterize the basic populations and distributions of salmon and resident fish throughout the proposed mine area, despite the fact such information is vital to conduct any type of restoration program.

Fast forward to 2014, when EPA, during its review of PacRim’s reclamation, mitigation and fish protection plans, noted PacRim had still failed to provide the basic information on which to make informed decisions regarding salmon habitat and other aquatic resources:

“The reports do not adequately document the inherent and significant uncertainty in creating (or recreating) functioning aquatic systems and providing successful compensatory mitigation for impacts of this nature and scale. EPA is unaware of any examples where a pristine and functioning anadromous stream and wetland system was impacted and then successfully restored at the scale proposed. The examples included in the FPP [fish protection plan] are not readily comparable with the current proposal.”25

23 Memorandum from Josh Brekken, ADFG Habitat Biologist, to Michael Daigneault, ADFG regional Supervisor, July 28, 2014. According to the memo, “[t]hese surveys documented anadromous fish populations in streams and lakes that were previously unsurveyed or that contained conflicting or limited baseline information. All of the areas that were surveyed completely during our visit contained coho salmon. Based on this fact, and the large amount of unsurveyed waterbodies in these watersheds, I believe the amount of anadromous fish habitat in the area has been under documented...”


25 EPA Region 10, EPA’s General Comments on the Revised Post-Mine Reclamation Plan Overview (dated August 2014), Conceptual Compensatory Mitigation Plan (CCMP) and Fish Protection Plan (both dated June 2014) for the proposed Chuitna Coal Project, Sept. 29, 2014, p.4 (emphasis added).
Similarly, the National Marine Fisheries Service (NMFS), which is the nation’s expert fisheries agency, concluded the Chuitna strip mine would cause permanent impacts to the Chuitna Watershed and associated salmon habitat. NMFS states that:

“...the applicant’s proposed stream restoration plan and supporting presentation highlights examples of stream restoration techniques widely recognized as the best available methods. However, the examples presented by the applicant represent restoration projects of far smaller scale stream realignments. These examples do not illustrate or represent stream restoration efforts at the size and scale of this mining operation where hydrogeomorphic processes are disrupted to a depth of 300 feet over several thousand acres. Stream restoration efforts at this scale would face many complications and impediments. We are aware of no example of successful salmon stream restoration at this scale.”

In addition to concerns raised by our state and federal agencies, a host of University scientists and other experts have reached similar conclusions. For example, one of the world’s most esteemed experts on aquatic ecology and habitat restoration is Dr. Margaret Palmer. Dr. Palmer is the Professor and Director of the National Socio-environmental Synthesis Center at the University of Maryland, and she played a central role developing a database and conducting analyses on over 38,000 stream restoration projects around the world.

In 2011, Dr. Palmer wrote a memo in response the DNR’s denial of the Unsuitable Lands Petition, which had been filed to make the point that Middle Creek – and other salmon streams – were not “suitable” for large scale coal strip mining, because they could never be returned to their pre-mining functions and values after such intensive development. In other words, we argued there is no way to build a new salmon stream from scratch after you’ve destroyed the wetlands, the riparian habitat, the streambed and the underlying hydrology that all go into the complex make-up of a wild salmon system.

Dr. Palmer’s memo is important because it methodically counters with peer-reviewed science every example offered by DNR and PacRim to show that somehow new salmon streams could be built from scratch. And much of her analysis focused on the fact that never before has anyone successfully restored the type of wild salmon systems found in the Chuitna watershed after such intrusive development. She concludes: “In short, if restoration is not possible on landscapes that have far fewer impacts to them than those proposed for the Chuitna River project, then

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we can say with certainty that such restoration efforts on the Chuitna post-mined land will not be possible."27

Another expert, Former ADFG Habitat Biologist Lance Trasky, has reviewed PacRim’s studies and proposed plans, and notes:

I have over 25 years of experience in analyzing and permitting projects affecting fish habitat, including large and small mines in Alaska, I am not aware of any instance where a salmon spawning and rearing drainage has been completely altered in the manner proposed for the Chuitna coal mine and then restored to its original productive state.28

Another point raised by Trasky and others highlights one of the more glaring gaps in PacRim’s work, which is the role of marine-derived nutrients within the Middle Creek and Chuitna watersheds.29 These marine derived nutrients consist of the organic matter spawned-out salmon and egg sacs deposit into natal streams, and they play a major role shaping ecosystem functions and the growth and condition of aquatic, riparian and terrestrial flora and fauna.30 And while the complete removal of Middle Creek will destroy this vital nutrient cycle, PacRim has failed to address this important issue, which will have far reaching effects throughout the Chuitna watershed and in Cook Inlet.

Yet another factor ignored by PacRim involves the complexities around climate change, and how anticipated changes in snowpack, rainfall and temperatures will affect hydrology and salmon habitat over the course of the project.31 For example, temperature monitoring conducted by Inletkeeper’s Science Team in the lower reaches of the Chuitna River from 2008-2011 already shows average temperatures too warm for spawning salmon according to state standards on an average of 37 days/year.32 As climate change ensues, winter stream flows are

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27 Memo entitled “Expert Comments on Denial of Unsuitable Lands Petition by Alaska Department of natural resources (DNR) dated 10/24/11,” from Dr. Margaret A. Palmer, Director, National Socio-environmental Synthesis Center, University of Maryland, to Robert Shavelson, Cook Inletkeeper, Nov. 11, 2011. See also, Margaret Palmer, Report on Chuitna Coal Project of PacRim Coal, Mar. 16, 2009).


29 Lance Trasky, Trasky & Assoc., Letter to Dan Sullivan, Dept. Natural Resources, regarding Petition to Designate the Streambeds of Anadromous Water Bodies and Riparian Areas within the Chuitna River Watershed, Alaska as Unsuitable for Surface Coal Mining Pursuant to AS. 27.21.260, Jan. 17, 2011.


31 Tom Meyers, PhD., Technical Memorandum: Detailed Statement of Findings and Decisions on Petition Requesting that the Streambeds of Anadromous Waterbodies and Associated Riparian Areas in the Chuitna River Watershed be Designated as Lands Unsuitable for All Types of Surface Coal Mining Operations, Nov. 15, 2011.

expected to increase, and summer flows to decrease, and warming temperatures will make salmon more vulnerable to pollution, predation and disease.

We have volumes of information from hydrologists, aquatic biologists, geologists, stream ecologists and other experts showing that it’s impossible to put back a wild salmon system after the types of impacts envisioned by the Chuitna strip mine, especially in a changing climate. I will submit those as part of the record, but at the most basic level it’s important to ask, “If PacRim has somehow figured out how to build new salmon streams from scratch, wouldn’t it make more sense to build some streams in Washington and Oregon before experimenting in Alaska?” It certainly couldn’t be a worse business model than trying to sell Alaska coal.

So, to wrap-up this section, when making the public interest determination, there’s no harm to any person from granting the water reservations for Middle Creek because such reservations will confer only benefits to Alaska and Alaskans, and the permitting processes underway can simply stay their course; if PacRim somehow finds a way to submit final mine, restoration and fish protection plans – along with other required documents – the State can always revoke or amend the water reservations if it is in the public interest.

And while we do not agree this is an either/or proposition, if DNR choses to treat it as such, the evidence is overwhelming that the public interest mandates keeping water in a wild salmon stream rather than allowing a corporation to dewater and mine through the stream to send coal to Asia. The economics support this position, the science supports this position and it comports with Alaska’s constitutional mandate to manage our resources for the maximum benefit of the people.

V. Conclusion

Finally, I want to introduce a book into the record called the “King of Fish.” It’s written by Professor David Montgomery at the University of Washington, and it’s an important book, because it tells the story of salmon. Specifically, it tells the story of the demise of salmon – and the once prolific runs that clouded rivers in Europe, and New England and the Pacific Northwest. And the central lesson we pull from the book is this: it wasn’t simple neglect that led to the loss of salmon fisheries across the globe; it was willful neglect. In other words, we knew what we were doing was wrong, and we did it anyway.

And that’s what we’re facing here today. We know a large scale coal strip mine will destroy wild salmon habitat forever. We know our complex systems are connected, and pulling one string from the ecological fabric weakens the entire cloth. We know coal aggravates climate change and ocean acidification, and we know Alaska is warming faster than most places on

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Earth. And we know this project is not financially viable until we see a business plan that shows that it is.

Governor Jay Hammond wisely applied a three part test to projects like Chuitna: Are the environmental impacts acceptable? Do Alaskans want the project? Does the project pay for itself? And by every measure, the answer to each of these questions is a definitive “no.”

Governor Walker rightly talks about a sustainable economic future for Alaska, and I can think of no other resource that forms the foundation for sustainable economy in our Great State than wild, healthy, Alaska salmon. And it was a breath of fresh air when Governor Walker took office and immediately set about forming Transition Teams, so he and Lt. Governor Mallot and their team could hear from Alaskans about important issues. And from the Fisheries Transition Team – which included a broad cross-section of Alaskans from diverse interests - came a unanimous recommendation: put fish first. Adopt a Fish First Policy for Alaska.

Now, through this water reservation proceeding, the Walker Administration can embrace that notion, and put fish first, and set a policy direction that will forever recognize the vital role wild salmon play to our people, our culture and our economy.

Mr. Schade, you and Commissioners Myers and Cotton and Governor Walker and Lt. Governor Mallott have an important decision in front of you. And let me say now, I have appreciated your engagement, your humor and your professionalism throughout this proceeding.

Thank you for the opportunity to testify today. Cook Inletkeeper would like to endorse the comments submitted on behalf of the Chuitna Citizens Coalition and the Alaska Center for the Environment, and would like to make a written copy of my testimony and all the attachments to it part of the record for this proceeding.
ATTACHMENTS:
(Presented in the order in which they are cited in the attached testimony)


Jeff Jessee, Executive Director, Alaska Mental Health Trust, Board of Directors Meeting, May 10, 2012.


Memorandum from Josh Brekken, ADFG Habitat Biologist, to Michael Daigneault, ADFG regional Supervisor, July 28, 2014.


EPA Region 10, *EPA’s General Comments on the Revised Post-Mine Reclamation Plan Overview (dated August 2014), Conceptual Compensatory Mitigation Plan (CCMP) and Fish Protection Plan (both dated June 2014) for the proposed Chuitna Coal Project*, Sept. 29, 2014.

Lance Trasky, Letter to Cook Inletkeeper, regarding *Review of Rejection of Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260*, Nov. 18, 2011.

Margaret A. Palmer, Director, National Socio-environmental Synthesis Center, University of Maryland, Memo entitled “*Expert Comments on Denial of Unsuitable Lands Petition by Alaska Department of natural resources (DNR) dated 10/24/11,“ to Robert Shavelson, Cook Inletkeeper, Nov. 11, 2011

Margaret Palmer, Director, National Socio-environmental Synthesis Center, University of Maryland, *Report on Chuitna Coal Project of PacRim Coal*, Mar. 16, 2009).


Lance Trasky, Letter to Cook Inletkeeper, regarding *Review of Rejection of Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260*, Nov. 18.


Tom Meyers, PhD., *Technical Memorandum: Detailed Statement of Findings and Decisions on Petition Requesting that the Streambeds of Anadromous Waterbodies and Associated Riparian Areas in the Chuitna River Watershed be Designated as Lands Unsuitable for All Types of Surface Coal Mining Operations*, Nov. 15, 2011.

TESTIMONY OF COOK INLETKEEPER
MIDDLE CREEK WATER RESERVATION HEARING
AUGUST 21, 2015

ATTACHMENTS:
(Presented in the order in which they are cited in the attached testimony)


Jeff Jessee, Executive Director, Alaska Mental Health Trust, Board of Directors Meeting, May 10, 2012.

John Talberth, PhD. & Evan Branosky, Center for Sustainable Economy, Net Public Benefits of the Chuitna Coal Project, June 2011.


Memorandum from Josh Brekken, ADFG Habitat Biologist, to Michael Daigneault, ADFG regional Supervisor, July 28, 2014.


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Lance Trasky, Letter to Cook Inletkeeper, regarding Review of Rejection of Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260, Nov. 18, 2011.
Margaret A. Palmer, Director, National Socio-environmental Synthesis Center, University of Maryland, Memo entitled “Expert Comments on Denial of Unsuitable Lands Petition by Alaska Department of natural resources (DNR) dated 10/24/11,” to Robert Shavelson, Cook Inletkeeper, Nov. 11, 2011

Margaret Palmer, Director, National Socio-environmental Synthesis Center, University of Maryland, Report on Chuitna Coal Project of PacRim Coal, Mar. 16, 2009).


Lance Trasky, Trasky & Assoc., Letter to Dan Sullivan, Dept. Natural Resources, regarding Petition to Designate the Streambeds of Anadromous Water Bodies and Riparian Areas within the Chuitna River Watershed, Alaska as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260, Jan. 17, 2011

Lance Trasky, Letter to Cook Inletkeeper, regarding Review of Rejection of Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260, Nov. 18.


Tom Meyers, PhD., Technical Memorandum: Detailed Statement of Findings and Decisions on Petition Requesting that the Streambeds of Anadromous Waterbodies and Associated Riparian Areas in the Chuitna River Watershed be Designated as Lands Unsuitable for All Types of Surface Coal Mining Operations, Nov. 15, 2011.

April 6, 2015

Kimberly Sager  
Statewide Water Reservation Specialist  
Department of Natural Resources  
Water Resources Section  
550 West 7th Avenue, Ste. 1020  
Anchorage, Alaska 99501

Dear Ms. Sager,

The Institute for Energy Economics and Financial Analysis (IEEFA) conducts research and analyses on financial and economic issues related to energy and the environment. A more detailed description of our work can be found in the appendix.

I write to supply comment to the Department of Natural Resources (“Department”) in its deliberations on the Chuitna Citizens Coalition application to reserve water within Middle Creek near Beluga, Alaska. This commentary is offered in response to the Department’s Notice of Application for Reservation of Water within Stream 2003/Middle Creek (LAS 27340- Main Reach; LAS 27436- Lower Reach; LAS 27437 – Middle Reach), dated February 23, 2015 and the subsequent Extension of Comment Period dated February 26, 2015. The application would reserve the use of the water in support of fishing and natural resource benefits currently enjoyed by Alaskan residents.

The alternative use for this water, proposed by Pacific Rim Coal LLC in another proceeding, is to supply the proposed Chuitna coal mine project. Recently, David Schade, the Department’s Chief of Water Resources, linked the two projects and characterized them as “either- or” propositions for the Department.

Summary of Proposed Chuitna Coal Project

The Chuitna Coal Project is a large open pit mining project proposed for the western shore of Alaska’s Cook Inlet. The project has been in some form of development since the late 1970’s. The current developer is Pacific Rim Limited. The project would consist of a 5,050 acre open pit coal mine, a 12 mile covered overland coal transport conveyor, a 4.5 mile power transmission line, mine access roads, a housing and airstrip facility, and a coal export terminal at Ladd Landing that would rely on a 10,000 foot trestle built into Cook Inlet to load Chuitna Coal onto transport ships destined for Asian ports. The entire project involves land owned by multiple

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1 http://dnr.alaska.gov/mlw/mining/largemine/chuitna/  
public and private parties, but the mine footprint is within lands owned by the Alaska Mental Health Trust. Pacific Rim holds a lease to mine that property. The full project involves reserves of over 1 billion tons. At full production the mine is expected to produce 12 million metric tons of coal per year, or approximately 268 million tons over the life of the mine. The Army Corps of Engineers (Corps) and other federal and state agencies are in the midst of a permitting and environmental analysis.

The markets for the coal that would be mined from Chuitna are purportedly various countries in the Pacific Rim – China, Japan, Korea, Taiwan and Vietnam. The letter speaks to the short and long term condition of the Asian thermal coal market. We have concluded that the Chuitna coal project is not viable in the current investment climate nor for the foreseeable future.

While Pacific Rim LLC has not published specific financial plans, it is fair to say that a robust Asian coal market is required for a new North American entrant to succeed. However, the project comes at a time when Asian coal demand is slowing, the coal market price structure has collapsed, and the investment consensus (see below) is that an overall decline is likely to continue. The factors influencing the global coal market are described in detail below.

**Background on global coal markets**

The total seaborne global coal trade (including all types of coal) in 2013 was 1.3 billion tons per year. The global seaborne thermal coal trade in the same year, according to the United States Energy Information Administration (EIA), was approximately 1.0 billion tons per year (Chuitna would produce thermal coal).

**Table I: Leading World Exporters of Coal (2013)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Steam</th>
<th>Coking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>426</td>
<td>423</td>
<td>154</td>
</tr>
<tr>
<td>Australia</td>
<td>336</td>
<td>182</td>
<td>22</td>
</tr>
<tr>
<td>Russia</td>
<td>141</td>
<td>118</td>
<td>60</td>
</tr>
<tr>
<td>USA</td>
<td>107</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>Columbia</td>
<td>74</td>
<td>73</td>
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<tr>
<td>South America</td>
<td>72</td>
<td>72</td>
<td>33</td>
</tr>
<tr>
<td>Canada</td>
<td>37</td>
<td>4</td>
<td>33</td>
</tr>
</tbody>
</table>

**Table II: Leading World Importers of Coal (2013)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
<th>Steam</th>
<th>Coking</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>327</td>
<td>250</td>
<td>77</td>
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<tr>
<td>Japan</td>
<td>196</td>
<td>142</td>
<td>84</td>
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<tr>
<td>India</td>
<td>180</td>
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<td>South Korea</td>
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<td>Germany</td>
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<td>43</td>
<td>8</td>
</tr>
<tr>
<td>U.K.</td>
<td>50</td>
<td>44</td>
<td>6</td>
</tr>
</tbody>
</table>


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4 Pacific Rim Limited, *Minor Air Permit Application*, Table 2.1 Chuitna Coal Mine, Life of Mine Parameters, January 28, 2008. An updated air permit application was filed in June 2013, the Life of Mine information is now considered Business Confidential [http://dec.alaska.gov/air/ap/docs/AQ0957MSS03Application061313.pdf](http://dec.alaska.gov/air/ap/docs/AQ0957MSS03Application061313.pdf)

Several important dynamics to consider are:

- Chinese coal imports rose to 327 million tons (tpa) in 2013. However, in 2014, Chinese coal imports dropped to 282 million tons and that level is now likely to drop even further. (Prior to 2008 China rarely imported more than 50 million tons of coal).

- Although much of the coal industry now sees India as the main bright spot for future coal demand, the Indian policy message on imported coal is mixed. India is likely to continue importing coal for next three to five years. Steam coal imports in 2013 were 142 million tons and could rise to 200 million tons in 2015. On the other hand, the Indian government was placed at a serious disadvantage in the years when coal and oil prices rose, contributing heavily to the countries deficit and weakening rupee. The country has considerable domestic coal reserves that have not been handled efficiently, even with global prices at their current lows, the cost of imported coal far exceeds that of coal that is mined and sold by the country’s state owned enterprise Coal India. The government has announced its intention to drive down the level of imports. The current minister has repeatedly stated a desire to end India’s reliance on imported coal.

If both China and India were to achieve substantial reductions of 50%, 200 million less tons of thermal coal would be needed for the seaborne trade.

Japan, Taiwan and Korea -- the principal sources of import demand of thermal coal in Asia outside of China and India -- represent about 300 million tons today. They, plus Vietnam (not listed above) would have to increase coal use by 200 million tons in five years just to keep markets at current production and shipping levels. As it stands, today’s production levels and the organization of the industry globally is unsustainable.

Indonesia, Russia, South Africa, Australia, and Colombia are all sources of coal to Asia, and all have plans to continue to export coal. They exported 860 lap of steam coal in 2013.

These provider nations are not without problems, but they do have structural advantages that make them better positioned than new entrants to manage import demand in Asia: 1) they have more than one type of coal; 2) shipping is over shorter distances and they have more flexibility on pricing, and 3) they have substantial reserves, which are likely to have extended lives as China and India cut back.

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7 Rohan Somwanshi, Global seaborne coal exports to decline in 2015, but not enough to rebalance markets, SNL Energy, March 27, 2015
8 http://in.reuters.com/article/2014/11/12/india-coal-imports-idINKCN0IW0FJ20141112
12 https://www.pwc.in/assets/pdfs/industries/power-mining/icc-coal-report.pdf, p.14
13 For a recent review of coal industry opinion on global markets and individual company outlooks see: Rohan Somwanshi, Global seaborne coal exports to decline in 2015, but not enough to rebalance markets, SNL Energy, March 27, 2015
14 Arch has outlined the problems of each of its competitors. They continue to produce more than US in export markets despite these drawbacks. Russia, Colombia and Australia have ambitious expansion plans. See: Arch Coal, Inc., Investor Presentation, May 2013, Slide 33
15 As markets remain constrained Australasia based producers have greater incentives to undercut NA coal producers – ad they have greater negotiating room as distances are shorter. All of the existing import and export relations are established and reflect broader trading and political relationships that are likely to continue.
Global coal prices are collapsing and the market is oversupplied

Many U.S. mainland coal producers are looking to export coal to Asia. In 2011 and 2012, rising global demand and prices on the thermal market gave this scenario plausibility. However, the global thermal coal market is now oversupplied. In the current market, and for the foreseeable future, U.S. coal producers (including Powder River Basin producers and the developers of the Chuitna mine) have no export opportunities. To the degree there are current international thermal market sales from the United States they are probably based on pre-existing contracts and are not profitable. The overall market for U.S. coal producers in the Pacific Rim is likely to get worse.

International thermal coal prices have collapsed (see Figure II) and are likely to stay low for the foreseeable future. The price of Newcastle Coal, an Australian coal product used as a global benchmark for thermal coal, fell dramatically from 2011 to the present. At its peak in January 2011, the price was $141.94 per ton. On March 19, 2015 the Newcastle price was $59.50 per ton. Looking forward, one Newcastle Coal Futures database identifies coal price contracts from 2016 to 2021 as trading in the $55.00 to $60.00 range (See Figure III). Persistent low prices are a sign that demand is falling. More to the point, the market gains that characterized the 2001 through 2011 period have faltered.

Figure II: U.S. Exports: Global Price Collapse

![Coal Price Collapse Graph](chart.png)

Source: [Index Mundi.com](http://www.indexmundi.com)

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17 For a detailed analysis of the nature of changes in the global seaborne thermal market as China’s 25% market share declines, see: Bernstein Research, 117-124.


According to one study produced in 2011 by the Center for Sustainable Economy, the Chuitna mine would not be feasible below a coal price of $91.29 per ton.\textsuperscript{21}

Two of America’s leading coal producers (Peabody Energy in late 2010\textsuperscript{22} and Arch Energy in early 2011)\textsuperscript{23} each provided an analysis of the Chinese coal markets using price points in the $90 per ton range. Each company was predicting net back profits (the amount of profit received by the U.S. coal producer from the international market price of coal minus transport and logistics costs) in the $20 per ton margins for this market. In 2012, China imported 327 million tons of coal (up from 200 million tons in 2011)\textsuperscript{24} and coal producers worldwide were predicting longer term growth from this source.\textsuperscript{25} More recently, Cloud Peak Energy stated it would require a Newcastle price between $80 and $90 per ton before selling coal to China.\textsuperscript{26}

During 2014, the market for Chinese imported coal and the global coal market more generally cooled (see discussion below) and global prices have collapsed.\textsuperscript{27} Most financial analyst projections have evolved to a clear consensus: as China reduces its import needs, sufficient capacity from the Pacific Rim producers (Australia, South Africa, Indonesia, Russia and perhaps China) exists to meet the needs of the remaining import countries, including India. U.S. and other North American coal producers will fill a niche market, but one not much larger than what exists today (see discussion below by Goldman Sachs, J.P. Morgan, Bernstein Research and Citigroup). This is also the conclusion of the extensively researched report released by Carbon Tracker Institute and the Institute for Energy Economics and Financial Analysis.\textsuperscript{28, 29} A new entrant, such as Chuitna, would face competition from Pacific Rim based producers, U.S. coal producers and Alaska’s primary producer, Usibelli Mining.

Usibelli mining has also seen reductions in its export sales. In 2011 the company reported peak export sales of 1.2 million tons. The last year for reported export sales is 2013. The company reported the sale of 630,000 tons.\textsuperscript{30} For the period 2007-2011 export sales drove Usibelli’s growth. Recent reports show the company is expecting another poor export year in 2015 due to weakening global prices.\textsuperscript{31} The bad economic news includes layoffs at Usibelli’s mine.\textsuperscript{32}

\textsuperscript{21} Center for Sustainable Economy, \textit{Net Public Benefit of the Chuitna Coal Project: Preliminary Assessment}, June 2011, p. 2-8. This study assembled a basic cost of production and set of capital cost assumptions based on various models. This was done in the absence of any business plan offered by Pacific Rim LLC. To update this study is beyond the scope of this comment; however the bottom line need for a market price in the $90 dollar range is corroborated by other similar coal industry market presentations. The lack of a business plan prepared by the sponsor and vetted by various Alaskan state officials is a peculiar lapse as the original permit decision is over 23 years old and the current market conditions have substantially deteriorated in recent years.

\textsuperscript{22} Peter Gartrell and John Miller, Peabody projections show lucrative Chinese market for PRB coal. Platts Coal Trader December 6, 2010

\textsuperscript{23} Peter Gartrell, Arch CEO sees $20 range for PRB coal to Asia, Platts Coal Trader1/31/11

\textsuperscript{24} http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=1&aid=3

\textsuperscript{25} Dan Lowrey, Woodmac sees half of US coal production exported by 2030, SNL, March 7, 2012.

\textsuperscript{26} http://seekingalpha.com/article/2175763-cloud-peak-energys-ceo-discusses-q1-2014-results-earnings-call-transcript?part=single

\textsuperscript{27} http://www.theguardian.com/environment/2014/oct/22/chinas-coal-use-falls-for-first-time-this-century-analysis-suggests


\textsuperscript{31} Usibelli’s reported 2014 exports are 513,000 tons. See: Alaska Railroad Briefing to Anchorage Metropolitan Area Transportation Solutions (AMATS) Policy Committee, March 26, 2015.

\textsuperscript{32} http://www.newsminer.com/business/coal-price-slump-hits-usibelli-coal-mine/article_8fe32ac2-af6e-11e4-8e0a-f79789f09d3c.html
Leading coal analysts see no market signals supporting new mine development

Like many other analysts, Wood Mackenzie (WM), a prominent global coal consultant has altered its once-optimistic position with regard to the export potential of the Asian market for U.S. producers.

The company published a broad analysis of domestic and global coal markets and export potential out of the U.S. in March 2012. WM projected U.S. exports would increase to 500 tap by 2030. (As a point of reference, in 2012 U.S. coal exports peaked at 125 million tons per year) This analysis was widely distributed within the coal and investor community. This bullish analysis and other industry statements emphasized several factors: 1) global thermal coal markets would expand from 1.1 billion tons per year to 2.2 billion tons per year by 2030; 2) India and China import demand would drive the increases; 3) Economic growth and specific additions to coal fired generation capacity were critical to coal industry future; and 4) U.S. market share would rise from 6% to 17% of the world market for thermal coal.

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Arch Coal, Inc., Investor Presentation, May 2013, Slide 12 or SNL.


However, in February 2015, WM\(^38\) reversed its outlook on Asian demand for U.S. coal exports. WM cited a slowing Chinese economy, a growing divergence between commodity price and market growth versus GDP growth, a change in economic priorities and new policy directions in China policy with regard to air pollution. This all added up to short and medium term problems for U.S. coal producers\(^39\) looking to export. The company is now projecting that the global thermal market will stay in a condition of oversupply through 2021 (plus or minus), depending on how many new mine projects are actually delayed.\(^40\) While still optimistic on long term trends in Asian coal, WM has tempered its enthusiasm for U.S. export potential.

SNL Energy maintains a database of coal industry information. It also offers a Coal Forecast consisting of Supply; Demand and Price estimations through 2025 (see Appendix I). SNL estimates for the Powder River Basin (PRB) show largely flat production levels, but declining overall projections for U.S. production. Overall production levels fall through 2025 from 1.008 billion tons per year in 2015 to 999 million tons by 2025. Southern PRB production is flat through 2025 and Montana coal (Northern PRB) drops slightly from 40 tap to 38 tap. Steam coal export estimates remain largely flat in the 44-47 million ton range through 2020 and then drop to 40 million ton per year by 2035 (See Appendix I).

In addition, the United States Energy Information Administration’s (EIA) underlying long-term outlook for Asian coal exports has been low and remains relatively stable. The Annual Energy Outlooks for 2012,\(^41\) 2013 \(^42\) and 2014 \(^43\) start with 2011 baseline figures between 8 and 12 tap (actual was 8.1 million tons) and rise to a range of 21.3 to 22.4 tap by 2030. This estimate supports, perhaps, 10 tap of new demand in an environment where there are six known U.S. competitors. Even when the EIA projected increases in overall U.S. coal exports, its view of Asian demand remained relatively static, lagging other U.S. regional coal producers.

**Independent investment analysts overwhelmingly project severe retrenchment in the global thermal coal market**

The four investment perspectives quoted below were originally released in June, July, September, and October 2013. The perspectives provide qualitative support that the export market for U.S. coal is at present under severe stress and is likely to remain so for the foreseeable future. The studies and several actions by these banks and analysts form a consensus that the international coal market is oversupplied. Global coal producers will face low prices and tight margins. Bernstein Research points to the structural nature of the changes stating the trend is not likely to reverse itself. Goldman Sachs says capital shifts from larger mining concerns suggest a significant move away from coal. J.P. Morgan concludes it is not

\(^38\) http://energyasia.com/blog/china-energy-demand-decoupled-significantly-gdp-says-wood-mackenzie-economist/
\(^40\) http://www.woodmac.com/public/media-centre/12526159
\(^41\) http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2012&subject=7-AEO2012&table=96-AEO2012&region=0-0&cases=ref2012-d020112c
\(^42\) http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013&subject=7-AEO2013&table=96-AEO2013&region=0-0&cases=ref2013-d102312a
\(^43\) http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014&subject=7-AEO2014&table=96-AEO2014&region=0-0&cases=ref2014-d102413a
economic to export coal at present. Citibank concludes that the end of the coal super cycle is here.

These trends will most likely continue as China’s need for coal imports diminish. When China buys less coal on the global market it drives down demand and price.

Bernstein Research concluded its work in the spring of 2013:

Decelerating power growth and structural weakness in other end markets, combined with more hydro, nuclear and renewables and more coal production and rail capacity in China, add up to the once unthinkable: zero net imports in 2015 and falling Chinese demand by 2016.

Globally, Chinese demand for coal has been the primary driver or the backstop behind every new investment in coal mining over the last decade; the “global coal market” ended with the collapse in price in 2012: regional miners will see almost zero demand in China from 2015.

Once Chinese coal demand starts to fall there is no robust growth for seaborne thermal coal anywhere; developed market demand is weak due to gas, environmental concerns or industrial activity; that leaves just one large structural growth market for seaborne coal: India.44

The Bernstein analysis concludes that the global thermal coal market will never recover.45 Bernstein correctly predicted that coal imports to China would decline in 2014.46

Goldman Sachs’ 2013 view of thermal coal markets cast a profile of a weak and declining market:

Earning a return on incremental investment in thermal coal mining and infrastructure capacity is becoming increasingly difficult. In the short term, a sharp deceleration in seaborne demand (we expect average annual growth to decline to 1% in 2013-17 from 7% in 2007-12) has moved the market into oversupply and caused a downward shift in the cost curve; we downgrade our price forecasts to US$83/t in 2014 and US$85/t in 2015 (down 13% and 11% respectively) and maintain a relatively flat outlook for the rest of our forecast period to 2017.

Mines are long-lived assets with a long payback period, and investment decisions today are sensitive not just to prices and margins today, but also to projections going well into the next decade. We believe that thermal coal’s current position atop the fuel mix for global power generation will be gradually eroded by the following structural trends: 1) environmental regulations that discourage coal-fired generation, 2) strong competition from gas and renewable energy and 3) improvements in energy efficiency. The prospect of weaker demand growth (we believe seaborne demand could peak in 2020) and seaborne prices near marginal production costs suggest that most

44 Bernstein Research, Asian Coal and Power: less, Less, Less…The Beginning of the End of Coal, Cover Page, June 2013. (Bernstein)
45 Bernstein, Executive Summary.
thermal coal growth projects will struggle to earn a positive return for their owners; in our view, this is reflected in the way diversified mining companies are reallocating their capital towards more attractive sectors.\(^\text{47}\)

Goldman Sachs’ price downgrade in 2013 was followed by actual price declines far greater than estimated. Goldman anticipated a price of $83 per ton in 2014. The average price for 2014 was $70 per ton.\(^\text{48}\) In January 2014 Goldman Sachs sold its stake in a coal port greenfield project in Bellingham, Washington a joint venture with SSA Marine Terminals (40+ million ton per year capacity).\(^\text{49}\)

In October 2013, J.P. Morgan analysts expressed their concerns regarding the ability of U.S. coal producers to access the global thermal coal market: “While the outlook for ILB [Illinois Basin] coal appears stronger than other basins, the region is not immune from the challenged coal market.” Further: “Export markets have been crucial in balancing supply-demand in the US; however, depressed international prices appear to have closed the door on new export contracts and could create domestic oversupply.”\(^\text{50}\) In 2014, the company continued to weigh in with its analysis of the global thermal coal trade estimating a decline of U.S. thermal coal exports through 2016 from 49 tap to 36 tap.

It’s not economic to export US coal at present, and while some sales are continuing; probably driven by take or pay commitments, we doubt new sales will be signed outside long standing relationships.

US coal exports are falling more quickly now, but with other countries apparently concluding it’s easier to drop costs rather than production, seaborne prices are reaching new lows.\(^\text{51}\)

In September 2013 Citibank\(^\text{52}\) offered its view identifying broad changes in Chinese GDP, pollution and energy policy, internal country improvements, rising influence of renewables and other energy sources to conclude that coal producer’s looking to enter the export market were going to find it very difficult to succeed.

As the range of forecasts for Chinese coal demand is wide, we believe investors should price in higher probabilities of lower coal demand. Optimistic long-dated coal prices may be unsupported. Although lower prices may spur demand growth elsewhere, the demand slowdown in China should more than offset such gains, in our view. Coal exporting countries that have been counting on strong future coal demand could be most at risk. The end of the supercycle should weigh on both the mining and equipment sectors. But sectors that excel at renewable integration, distributed generation, transmission could benefit the most.


\(^{49}\) http://www.reuters.com/article/2014/01/08/goldman-port-sale-idUSL2N0KI00U20140108


\(^{52}\) https://ir.citi.com/z5yk080HEXZtolax1EnHssv%2Bzm4Pc8GALpLbF2Ysb%2Fli21vGjprPCVO%3D%3D
In October 2014, several major investment banks announced they would not provide financing to support a large coal mining and export infrastructure in Australia. This is one of the largest proposed mining initiatives in the world that would compete for the same Asian markets as the Chuitna project. The unwillingness of banks to finance this project reflects the view that the markets are oversupplied and will remain so for the foreseeable future.

The Chuitna Coal project faces competition from U.S. Coal Producers

Pacific Rim LLC faces competition from U.S. coal producers. Arch, Coal, Peabody Energy, Cloud Peak, Alpha Natural Resources, First Energy/Gunvor and Resource Capital Funds are all devoting resources to compete for sales to Japan, Korea, Taiwan and Vietnam. These U.S. producers are pressing ahead with plans from two new coal ports in Washington State. These ports would provide coal export capacity of 88 tap. Cloud Peak and Arch also have reserved port space at the Ridley Terminal in Canada. Arch Coal and First Energy/Gunvor are moving forward with mine expansion projects at Otter Creek and Bull Mountain. All of these companies acknowledge headwinds on the export front. Capital markets have reacted negatively to these plans. The SNL Coal Index, an index of leading U.S. coal producers, has lost 69.5% of share value since March 2010.

In the short term there are no signals for new mines in North America, not for U.S. domestic coal or export needs. In the medium term, through 2021, there are also no price or demand indicators that suggest a new mine entrant in the Asian market would be successful. Colin Marshall the CEO of Cloud Peak Energy recently stated that the Japanese and Koreans were looking at coal demand 30 and 40 years from now. This level of speculation reflects a realistic view of the long term global thermal markets. They will not rebound anytime soon.

Within the United States coal producers are currently going through a period of decline and consolidation. For example, 26 U.S. coal bankruptcies have gone bankrupt through 2013. Most of these producers are small and concentrated in the southeast. However, as the coal industry continues to be battered discussion of major reorganizations and bankruptcy among larger coal companies across the United States is a constant issue.

The Chuitna Coal project faces competition from Alaska-based Usibelli mining

Currently, the Usibelli company produces approximately 1.3 million tons of coal annually. In October 2014 Alaska state mining officials granted the company a new permit to mine an additional 500,000 tons per year. Half of Usibelli’s historic production goes for exports to Japan, South Korean and Taiwan and the remainder is used in coal fired power plants in Alaska. As mentioned above Usibelli has seen a reduction of 57% in coal export volumes in just three

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55 SNL/Peabody Energy/StockChart/SNL CoalIndex/5 years/March 30, 2015.
57 Darren Epps, Bankruptcies continue to rock coal companies in ’13, but hope for the survivors, SNL, December 5, 2013.
58 Christopher Coats, Market value of U.S. coal producers continues to tumble, led by met coal producers, SNL, March 13, 2015. See also: http://247wallst.com/commodities-metals/2014/05/28/more-bankruptcies-coming-for-top-coal-stocks/
59 http://www.adn.com/article/20141014/state-grants-permit-usibelli-disputed-wishbone-hill-mine-project
years, down from 1,200,000 tons in 2011 to just 513,000 tons in 2014. There is every indication that the plan for the coal from the mine is for sale in Asian markets. Current market conditions may require the mine owner to consider competing for sales to Alaskan coal plants.

**Conclusion**

The Chuitna coal project would serve little purpose in this shrinking market over the next several decades. There is no need for the mine and no price structure to support it.

Sincerely,

[Signature]

Tom Sanzillo  
Director of Finance  
tomsanzillo@yahoo.com
Appendix

IEEFA Background

IEEFA’s mission is to accelerate the transition to a diverse, sustainable and profitable energy economy and to reduce dependence on coal and other non-renewable energy resources. Among the many research and analytical studies we have prepared, several have relevance in this proceeding.

IEEFA co-authored, with Carbon Tracker Institute, a major study of global thermal coal markets in September 2014. The study, which used proprietary data, is arguably one of the most comprehensive, publicly available reviews of the current global coal markets, and includes country-by-country reviews of macro trends. The report also models future market activity.

IEEFA has also produced studies on coal and coal mining finance in the United States, Australia’s Galilee Basin, and India. IEEFA has produced numerous financial studies that cover U.S. coal plants, state regulation of coal plants, federal and state subsidies and competitive energy markets. IEEFA personnel serve as expert witnesses in regulatory proceedings. Over the course of their individual careers, IEEFA personnel have reported or provided expert testimony in most states in the United States on energy and electricity issues.

Biography of Tom Sanzillo

Tom Sanzillo joined the Institute for Energy Economics and Financial Analysis (IEEFA) as director of finance in 2012. His reports on the U.S. coal industry and coal markets have resulted in multiple investigations by federal oversight bodies including the Securities and Exchange Commission, Congress and the Government Accountability Office (GAO) and the cancellation of several proposed coal plants. From 1990 to 2007, Sanzillo served in senior management positions to the publicly elected chief financial officers of New York City and New York State. From 2003 to 2007, he served as the first deputy comptroller for the State of New York. Among his responsibilities was the management of a $150 billion globally invested public pension fund. He continues to write on government and public finance issues, and runs his own company, T.R. Rose Associates. Sanzillo’s most recent publication on New York State government and finance is part of the 2012 Oxford Handbook of New York State Government and Finance.
August 19, 2015

Kimberly Sager
Statewide Water Reservation Specialist
Department of Natural Resources Water Resources Section
550 West 7th Avenue, Ste. 1020
Anchorage, Alaska 99501

Dear Ms. Sager,

I write to provide additional comments to our April 2012 letter to the Department of Natural Resources (“Department”) in its deliberations on the Chuitna Citizens Coalition’s applications to reserve water within Middle Creek in the Chuitna watershed near Beluga, Alaska. This commentary is offered to assist with the August 21, 2015 public hearing and subsequent decision-making.

I am the Director of Finance for the Institute for Energy Economics and Financial Analysis. My work for the last eight years involves extensive research on the financing of coal mining and coal plants. During my career I have held senior financial management positions in the State and City governments of New York, including auditing, contracting, investment of the New York’s $156 billion pension fund and oversight of a bond portfolio in the hundreds of billions of dollars.

This letter responds to public statements made by the proponents of the mine regarding the quality and marketability of the coal, and offers some additional information that may assist the Department.

In summary, based upon public disclosures by the developer, the coal from the proposed Chuitna mine has no inherent competitive advantage over other coal products currently competing in the global marketplace. Chuitna coal contains average levels of sulfur for a low-sulfur product. Chuitna coal contains a low heat value. Companies that produce similar coal, with similar sulfur levels and better heating values, are having difficulty in today’s marketplace, and coal with similar sulfur levels and similar heat levels to Chuitna coal has no export potential currently and for the foreseeable future.
Global coal markets are oversupplied and there is no evidence that an Alaskan mine with no product advantage would succeed as a new entrant in the global thermal market place. Difficult market conditions have persisted for the past several years and will continue for at least the next six years, according to the best available data. The condition of oversupply has driven world coal prices to historic lows. If this project goes forward, it is unlikely that the State of Alaska will receive the developer’s proposed $12.5 million in annual new revenues from the sale of coal from Chuitna.

PacRim is asking the State of Alaska to make an economic and financial judgment on the proposed mine, even though the company has not set forth its current, updated business assumptions regarding the mine in the form of a coherent business plan. A business plan would contain at minimum the cost of production of coal from Chuitna, costs of capital, projected revenues based on an estimated market price (and presumably some specified market), an estimate of operating margins and a general debt/equity plan. None of this information is publicly available.

**PacRim’s Low Sulfur Coal Product Is Quite Typical of Other Low Sulfur Coal Products – It Has No Competitive Advantage**

Much of PacRim’s public discussion around Chuitna emphasizes the low-sulfur content of the coal. The company asserts that this characteristic will provide Chuitna coal with a competitive edge when it is marketed to other countries. The PacRim mining presentation¹ that is currently available to the public lists the heating value of the coal at between 7,650 and 8,800 Btu/lb with a sulfur content of 0.34 percent. This coal is considered sub-bituminous (low heat content) and low sulfur content.

First, describing Chuitna coal as “ultra low” sulfur coal is misleading. Chuitna coal has a sulfur content that is the same as the average Powder River Basin (PRB) coal product, according to the National Energy Technical Laboratories (NETL) (See Table I).² The table summarizes the weighted average sulfur content of coals from the Powder River Basin at 0.34 percent. This is the average sulfur level of what is typically designated low-sulfur coal.

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Second, the use of the term "ultra" does not appear to have a specific uniform standard that is accepted by independent standard setting agencies like NETL or the United States Energy Information Administration (EIA). The EIA does not recognize the term. The term seems to be used more as a promotional device. Peabody Energy has used the term ultra low sulfur coal on product with 0.55 percent sulfur. As noted in the footnotes of the NETL chart, the term used for coal with exceptionally low levels of sulfur is “super compliance” coal. This term is reserved for coal with 0.2 percent sulfur or less. There are some commercial testers that use the term “ultra low sulfur” coal, but there the standards are different. According to PacRim’s presentation, its coal product would not meet the definition of “super compliance.” The coal from Chuitna would therefore not enjoy any of the competitive advantages of this class of coal. It is typical low sulfur coal.

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The two most significant companies that have exported low-sulfur coal off the West Coast of the United States into Pacific Rim markets for several years are Cloud Peak Energy (which runs Spring Creek mine, Montana) and First Energy/Gunvor (which runs Bull Mountain mine, Montana).

Table II: Comparison of Chuitna Heat Value and Sulfur Content with Spring Creek and Bull Mountain Mines

<table>
<thead>
<tr>
<th>Mine</th>
<th>Heating Value (Btu)</th>
<th>Sulfur Content (lb/mmbtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chuitna Mine</td>
<td>7,650-8,800</td>
<td>0.34</td>
</tr>
<tr>
<td>Bull Mountain (Signal Peak)</td>
<td>10,300</td>
<td>.038 -.043</td>
</tr>
<tr>
<td>Spring Creek</td>
<td>9,350</td>
<td>0.28-0.38</td>
</tr>
</tbody>
</table>

Coal from the two Montana mines noted above have higher sulfur levels and superior heat content compared to what Chuitna would produce. Both Cloud Peak’s Spring Creek and First Energy/Gunvor’s Signal Peak mines have found niche markets in the Pacific Rim. But total coal exports from the U.S. to Asia have peaked at 12 million tons per year, and just this year, Cloud Peak announced that its shipments to Asia would decrease from 6.3 mtpa to 4.3 mtpa, or 46 percent. Cloud Peak is the most successful of the publicly traded companies that produce PRB coal that goes to Asia, specifically to Korea, Taiwan and Japan. Its second-quarter earnings statement estimates further shipment will decrease in 2016 and indicates uncertainty about any market turnaround. Its current sales to Asia are losing money.

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4 IEEFA owns a license from SNL Energy for its database of United States mines. The information from the database comes from various filings (including EIA Form-423). These filings are made by coal companies doing business in the United States for each coal shipment. SNL Energy, Signal Peak, Power Plants Served (2011-2015), % Sulfur. The specific data from the system is available to the Department upon request.

5 SNL Energy, Spring Creek, Power Plants Served (2011-2015), % Sulfur.


Alpha Natural Resources, Arch Coal and Peabody Energy have all announced plans to ship PRB coal to Asia. Their products are comparable to Chuinna coal in their heating value and sulfur content. These companies are not reporting any significant sales activity to Asia, however, and Arch Coal has reported that it is now making penalty payments to Canadian ports under its export agreements with those ports. The company pays a penalty when it fails to ship coal for which it has reserved terminal space.

Alpha Natural Resources, Peabody Energy, Arch Coal and Cloud Peak are all in various stages of financial distress. All of these companies have lost from 80-95 percent of their value in recent years. None of their efforts to ship PRB coal to Asia has resulted in meaningful levels of exports. U.S. coal producers continue to press for export deals even in the weak market, however, and PacRim will face competitive pressures from these U.S. producers. Some of these competitors have better-quality products, and all have the reserve capacity to compete.

PacRim also faces competition from non-U.S. coal producers. Indonesian\(^8\) and Russian\(^9\) coal products are of similar low-sulfur content and similar heat content. Coal produced in each of those countries more often than not has a distinct transport-cost advantage because it is mined closer to China, India, Taiwan, Japan and Korea. Low-sulfur demand is not the entirety of the global thermal-coal market. The entire market is oversupplied and coal producers from South Africa, Australia and Colombia are also looking to ship coal to Asian markets.

Our analysis is not based on current market conditions alone. As we noted in our April letter, we pay careful attention to coal markets around the world. Table 2 has been updated from our April 2015 letter; it shows how the outlook for coal prices remain about the same through 2021 at below $60 per ton. As we noted, too, in our April letter, most of the planning for expansion


of coal-export facilities emerged during a period when prices spiked—as when Newcastle coal prices peaked at $140 per ton in 2011. The current Newcastle price is $59.40 per ton.\(^\text{10}\) Such prices are an indication that new coal mines are not needed.

We do not limit our analysis to quantitative assessments of current and future markets and our views are shaped in part by credible information from reputable news organizations. Major business news outlets, coal industry trade publication and web-based reporting organizations have been reporting for some time now on the oversupplied coal market and its many ramifications. Reuters,\(^{11}\) the Wall Street Journal,\(^{12}\) SNL,\(^{13}\) Business Insider,\(^{14}\) Bloomberg,\(^{15}\) Minewatch, and Indonesia Investments\(^{16}\) have all reported on the depth of the decline of the industry, its causes and the likelihood of its continuation.

The two major economies that drive the global thermal coal trade are China and India. China has announced its intention to decrease the amount coal it imports, and 2014 was the first year in almost a decade in which Chinese coal imports declined.\(^{17}\) It is expected that this trend will continue. India has announced it will cease importing coal over the next several years. While 2014 saw an increase in imports to India, the first part of 2015 has seen a slowing of the import rate.\(^{18}\)

We supplied substantial background in our April letter on the importance of Chinese and Indian import demand to the global coal trade. Even if these countries burn more coal in the coming years, they are likely to get that coal from Chinese and Indian mines. As they cut demand for imported coal, the other supplier countries simply intensify their sales efforts to a much smaller market. The competition increases, pricing is tighter and there is little room for new entrants.

The coal industry itself has acknowledged oversupplied markets in every region of the world that has an active interest in coal markets. The CEO of Alpha Natural Resources, a major player in the global metallurgical market (and a thermal coal exporter) has acknowledged that coal markets are in more than a cyclical downturn;\(^{19}\) Glencore, a

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\(^{10}\) http://ycharts.com/indicators/australia_coal_price
\(^{11}\) http://www.reuters.com/article/2015/08/11/us-column-russell-coal-asia-idUSKCN0QF14220150811
\(^{12}\) http://www.wsj.com/articles/as-coal-prices-fall-miners-cut-output-1433269071
\(^{13}\) https://www.snl.com/MobileX/UI/Pages/News/Article.aspx?cdid=A-32872208-12845&FreeAccess=1. SNL maintains a running tally of U.S. coal mining bankruptcy filings. There have been 36 such filings in the last three years. The loss of employment and revenue to state and local government has been steep.
\(^{17}\) http://www.worldcoal.com/coal/29072015/Chinese-market-remains-oversupplied-with-coal-on-lower-consumption-2651/
\(^{18}\) IEEFA has commented extensively on the program by the Indian government to decrease imports. http://ieefa.org/india-electricity-sector-transformation/
\(^{19}\) http://trib.com/opinion/columns/crutchfield-alpha-is-restructuring-for-the-future/article_a47d5d8b-d599-5a78-a7af-22ad44173cbc.html
global mining concern, has announced more cuts in production and staff in the wake of persistent low prices;\(^\text{20}\) BHP has issued investor warnings about long-term oversupply issues;\(^\text{21}\) Teck Resources has cut back plans for new mines in Canada in the wake of weak markets;\(^\text{22}\) Indonesian coal producers are looking at new strategies to address the drop in prices and shrinking markets;\(^\text{23}\) and South African companies report cutbacks due to oversupply in the markets.\(^\text{24}\)

The depth of the problem also has hit Alaska’s most significant coal producer, Usibelli Coal. Recent reports indicate that the company has lost 57 percent of its production since 2011. Most of the loss is attributed to diminished demand from Usibelli’s global trade partners.\(^\text{25}\)

**Conclusion**

The PacRim proposal for the Chuitna mine development is based on unsupported statements about the quality of the coal and speculative financial assumptions about coal prices and the revenue potential for the state. Such a speculative investment carries an exceedingly low likelihood of success on its merits within a reasonable time frame. At best, this mine would underperform, and like the rest of the coal industry in the U.S., leave local and state governments with weaker budgets, companies with bankruptcies or distressed sales and communities with economic disruption and layoff notices. While the Chuitna mine proposal purports to offer employment, revenues and robust economic activity, its developer offers little to support these promises.

Sincerely,

Thomas Sanzillo  
Director of Finance

\(^\text{25}\) [http://www.adn.com/node/2777546](http://www.adn.com/node/2777546)
On May 10, 2012, the Alaska Mental Health Trust had their regular meeting (agenda) and the CEO spoke at one point about coal and climate change. In short, CEO Jeff Jessie compared owning coal resources to owning asbestos before it was recognized as a hazard. It's valuable, but as recognition that the hazards of asbestos came to bear it lost its value. So AMHT should get value from its coal in the short term, so it isn't stuck holding the ball when values plummet. The original audio and transcript are below.

Audio File (MP3)

"...you know there are people that, for whom the concern is the fish, and with the Chickaloon and Chuitna we're going to have a very good story to tell about that. There are however a big group in that negative who are against coal because of the global warming issues and the carbon emissions issues. That's the one issue we can't do anything about other than sell our coal before the environment becomes so negative towards that that it's no longer an economic resource, like asbestos. Now is not a good time to invest in asbestos, but there was a time when asbestos was a good, a good resource to own. And we don't want to be in that position with coal where we had a lot of coal when coal was marketable and we end up 20, 25 years down the line when coal is no longer a" (Jeff Jessie, CEO)

"Coal is - let me just speak out in favor of coal as well - it's an evolving resource. There's obviously been some old and dirty plants in the past, but there are more and more ways of using coal that are clean as well. I don't think we'll ever see coal go away as an energy source. We'll see it evolve, and we'll see different ways of harvesting it and different ways of converting it to energy either through turning it into - like Linc is hoping to do on our property - to turn it into clean coal - or turn it into clean sulfur-free syngas and make a variety of products out of that. So we're watching it evolve but right now clearly - right now there's a demand for coal - for our coal pretty much worldwide and it would be a shame not to capitalize on that opportunity." (Greg Jones, Land Trust Office?)

Attached Files
990.5 KB
TLO Jeff Jessie Sell the coal before CO2 is negative.mp3
Date Created: 5th December 2012
Net Public Benefits of the Chuitna Coal Project

A Preliminary Assessment

Prepared for Cook Inletkeeper

By

John Talberth, Ph.D.²
Evan Branosky³

June 2011

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¹ Generous support for this research was provided by the Alex C. Walker Foundation through a grant to Cook Inletkeeper.
² Senior Economist, Center for Sustainable Economy, jtalberth@sustainable-economy.org.
³ Environmental Policy Fellow, Center for Sustainable Economy, ebranosky@hotmail.com.
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**About the Center for Sustainable Economy**

Center for Sustainable Economy consults with governments, businesses, universities, and non-profit organizations both nationally and internationally to analyze complex issues and implement solutions to speed the transition to a sustainable world. Our professional services include ecological economics, planning, sustainability analysis, on-line tools, and expert support for litigation and administrative advocacy. Current areas of emphasis include:

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- Carbon footprint analysis
- Sustainability analysis
- Public policy
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- Sustainability on-line
- Sustainability education
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- Legislative analysis

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Executive Summary

Along the western shore of Alaska’s Cook Inlet, the Army Corps of Engineers (Corps) and other federal and state agencies are in the midst of a permitting and environmental analysis process for the Chuitna Coal Project – the largest strip mine in Alaska’s history. The project would consist of a 5,050 acre open pit coal mine, a 12 mile covered overland coal transport conveyor, a 4.5 mile power transmission line, mine access roads, a housing and airstrip facility, and a coal export terminal at Ladd Landing that will rely on a 10,000 foot trestle built into Cook Inlet to load Chuitna Coal onto transport ships destined for Asian ports. At full production the mine is expected to produce 12 million metric tons per year for 25 years.

The project is anticipated to have a wide range of significant impacts to sensitive aquatic and terrestrial ecosystems of great economic importance to the region. Of particular concern is the extensive loss of salmon habitat and the commercial and recreational fishers that depend on this resource. Over 11 miles of highly productive salmon bearing streams could be lost. The Cook Inlet beluga whale, whose critical habitat was recently designated within the project area, is also at risk since its depleted population relies heavily on fish that congregate at the mouths of the Chuitna River and because it is sensitive to human disturbance. Scenic and aesthetic values associated with Cook Inlet’s wildlands will also be degraded. The project will affect a high value subsistence use area that is —a part of the economic, cultural, and social well being of the inhabitants in the area.” The project’s footprint will impact 1,830 acres of wetlands that provide valuable ecosystem services such as water filtration and flood mitigation. Recreational uses that include hunting, sport fishing, trapping, snow machining, berry picking, camping and hiking will be displaced.

But perhaps the greatest economic risk from the project is its contribution to global warming and hazardous air pollution in areas where Chuitna coal will be combusted. Each stage in the life cycle of coal—extraction, transport, processing, and combustion—generates a waste stream and carries multiple hazards for public health and the environment. Emissions of carbon dioxide, methane, nitrous oxide, sulfur dioxide, particulate matter, mercury and other pollutants from the burning of coal exact a heavy economic toll – $175 to $523.3 billion each year in the United States alone by one recent estimate. 9

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The potential severity of environmental and economic impacts associated with the project necessitates the highest standards of analysis throughout the permitting process. Indeed, federal agencies are expected to rely on the best scientific information and methods available in the analysis of projects of this size and magnitude. These methods require that the Corps and its federal and state partners analyze the Chuitna Coal Project from the standpoint of net public benefits, and not the narrow perspective of financial benefit to project investors.

Two primary metrics are used in a net public benefits analysis: net present value and the benefit cost ratio.\textsuperscript{10} The standard criterion for deciding whether a government policy, program, or project can be justified on economic principles is net present value – the discounted monetized value of expected net benefits (i.e., benefits minus costs).\textsuperscript{11} NPV is a measure of the absolute magnitude of the gain or loss to society.

The benefit-cost ratio is simply the present value of benefits divided by the present value of costs. A benefit-cost ratio above 1.0 is indicative of a policy, program, or project that has a NPV > 0 and is economically worthwhile from a public perspective. A benefit-cost ratio of 1.0 represents the lowest value that should be considered for public support as long as the analysis incorporates all significant costs and benefits and if uncertainty is relatively low. A benefit-cost ratio below 1.0 is indicative of a policy, program, or project that has a NPV < 0 and is not economically viable from a public perspective.

The Corps has operationalized the net public benefits standard in its guidelines for evaluating national economic development (NED) and regional economic development (RED) benefits associated with a proposed project. Such procedures require a full inventory of significant costs and benefits, both social and private. In this study, we report on the potential magnitude of net public benefits associated with the Chuitna Coal Project should it continue through the permitting process. The preliminary analysis is based on publically available information as of April 2011, and will be refined as more detailed financial and economic information is released.

With respect to national and regional economic development benefits, key findings include:

- The primary national economic development benefit associated with the project is the net revenues that will be earned from the sale of Chuitna Coal in the Asian market. Four price scenarios are modeled that reflect various policy options with respect to development of energy efficiency and clean fuels. Under the most optimistic scenario, Chuitna coal may fetch an average price of $125 per metric ton over the 25-year project life. Under a scenario where major investments in renewable energy reduce the demand for coal, average prices may be in the $74 per metric ton range. Four price scenarios and

\textsuperscript{11} Office of Management and Budget (OMB), Circular A-94 (Revised), Section 5(a). Available at: http://www.whitehouse.gov/omb/circulars/a094/a094.html.
two with respect to delivered coal costs suggest a range of net revenues of -$2.84 to $15.5 billion in present value terms.

- Importantly, if the low price scenario becomes likely due to more concerted policy commitment to low carbon development in Asia, the Chuitna Coal Project would not be viable even from a purely financial standpoint.

- Regional economic development benefits include jobs, income, and revenues generated for state and local government from royalties, taxes, and fees. Current data suggests that the project would generate 471 – 575 jobs and $26 to $31 million each year in personal income taking into account direct, indirect, and induced effects of spending as money circulates through the regional economy.

- Royalties, rents, taxes and fees are more uncertain, but could range between $14 and $20 million per year for state and local government.

With respect to national economic development costs, key findings include:

- Important categories of NED costs that can be estimated with publically available information include capital and operating costs, transportation costs, and non-market costs associated with carbon emissions damage, air quality damages, and lost ecosystem services.

- Publically available information, including mine cost models, preliminary cost estimates published by the National Energy Technology Lab, estimates supplied by PacRim, and recent coal cargo freight rates suggest a delivered coal cost of $55.26 to $88.05 per metric ton to Asian ports. Transportation costs are the most uncertain, and are the most significant source of variation in the delivered coal cost estimates.

- Carbon emissions damage associated with emissions throughout the life cycle of Chuitna coal would generate a present value cost of $17.26 billion over the mine’s 25 year life, or $57.53 per metric ton of production.

- Air quality damages associated with emissions of sulfur dioxide, nitrous oxide, and particulate matter would generate a present value cost of $53.09 billion over the mine’s 25 year life, or $176.98 per ton of production.

- Ecosystem service damages associated with lost fisheries, wetlands, and passive use values for both terrestrial and marine ecosystems degraded by the project’s infrastructure would generate a present value cost of $2.08 billion over the mine’s 25 year life, or $6.94 per metric ton of production.

With respect to the project’s overall net public benefits, key findings include:

- Even under the most optimistic price scenario, the social costs of the Chuitna Coal Project are likely to exceed benefits by a wide margin.
Taking all relevant costs into account suggests a NPV range of -$57.23 to -$75.27 billion and a benefit cost ratio of .3134 to .1713, meaning that costs exceed benefits by a factor of 3 to 6 (Table ES-1).

Social costs could range between 193 and 604% of market price, a finding that corroborates the range published in existing literature.12

Given this, the only way the Chuitna Coal Project could proceed in a manner consistent with net public benefits is a tax on production that recoups these externalized costs or major reconfiguration of the project to internalize or mitigate these damages.

Table ES-1: Net Present Value (billions) and Benefit-Cost Ratio under the Four Price Scenarios and Delivered Costs of $52.26 and $88.05/ Metric ton

<table>
<thead>
<tr>
<th>Asian Price Scenarios:</th>
<th>High coal cost</th>
<th>High oil price</th>
<th>Reference case</th>
<th>Low coal cost</th>
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<tbody>
<tr>
<td></td>
<td>NPV</td>
<td>BCR</td>
<td>NPV</td>
<td>BCR</td>
</tr>
<tr>
<td>Delivered cost of $52.26/ Metric ton</td>
<td>-57.23</td>
<td>0.3134</td>
<td>-63.56</td>
<td>0.2374</td>
</tr>
<tr>
<td>Delivered cost of $88.05/ Metric ton</td>
<td>-64.70</td>
<td>0.2876</td>
<td>-71.04</td>
<td>0.2179</td>
</tr>
</tbody>
</table>

As the permitting process unfolds, more detailed information on Asian market conditions, project development and annual operations costs, transportation costs, tax liabilities, and project configuration will make more refined estimates possible. However, given the wide margin of social costs over national economic development benefits estimated in this preliminary analysis and the fact that our estimates corroborate figures reported in the literature, it is unlikely that future refinements would affect project economics in any significant way.

This underscores the dilemma of developing new coal sources in an era of global warming. While market demand may support new coal mine development from the perspective of project investors, such projects are often not justified from a net public benefits perspective because they generate social costs far in excess of private financial benefits.

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Section 1: Regulatory Framework

As with all federal agencies, the U.S. Army Corps of Engineers (Corps) has an obligation to demonstrate that projects authorized or facilitated by the agency are justified on the basis of net public benefits. As such, the economic analysis undertaken in support of the Environmental Impact Statement (EIS), Clean Water Act Section 404 permitting decisions and other authorizations for the Chuitna Coal Project must disclose whether or not the project is economically feasible from the public perspective taking into account all relevant market and non-market benefits and costs. This net public benefits accounting framework is essential to sound decision making. In this section, we identify and discuss the essential components of a net public benefits analysis relevant to the Chuitna Coal Project.

1.1 Net Public Benefits Framework and Key Components

It is clear that development of the Chuitna Coal Project will require considerable involvement by public agencies at the federal, state, and local levels. At least four federal agencies will be participating in project decisions: the Corps, the EPA, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (Appendix 1). As of yet, it is unclear whether or not the Corps will be providing cost share assistance for the project’s general navigation features or whether or not the project will receive other forms of public finance such as support from the Alaska Industrial Development and Export Authority’s Development Finance Program. Either way, the significant involvement by federal and state decision makers in this project requires that the economic feasibility of the Chuitna Coal Project be analyzed from a net public benefits perspective through benefit-cost analysis and not the narrow financial perspective of private investors.

Benefit-cost analysis (BCA) compares the present value of the social benefits of a public policy, program, or project against the present value of social costs. There are two fundamental results from performing a benefit-cost analysis: 1) net present value (NPV); and 2) benefit-cost ratio. The “present worth” of a project is commonly referred to as its NPV. The standard criterion for deciding whether a government policy, program, or project can be justified on economic principles is net present value – the discounted monetized value of expected net benefits (i.e., benefits minus costs). NPV is a measure of the absolute magnitude of the gain or loss to society. As described by the Office of Management and Budget (OMB), net present value is computed by assigning monetary values to all benefits and costs – regardless of who enjoys or incurs them – discounting future benefits and costs.

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13 For example, AIDEA owns and operates the Delong Mountain Transportation System, used exclusively by Teck’s Red Dog Mine.
15 Office of Management and Budget (OMB), Circular A-94 (Revised), Section 5(a). Available at: http://www.whitehouse.gov/omb/circulars/a094/a094.html.
using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Importantly, “programs with positive net present value increase social resources and are generally preferred. Programs with negative net present value should generally be avoided.” Stated more precisely, projects that attain an NPV greater than 0 are worth investing in – the benefits over time outweigh the costs over the life of the project.\(^\text{16}\)

The benefit-cost ratio is simply the present value of benefits divided by the present value of costs. A benefit-cost ratio above 1.0 is indicative of a policy, program, or project that has a NPV > 0 and is economically worthwhile from a public perspective. A benefit-cost ratio of 1.0 represents the lowest value that should be considered for public support as long as the analysis incorporates all significant costs and benefits and if uncertainty is relatively low. A benefit-cost ratio below 1.0 is indicative of a policy, program, or project that has a NPV < 0 and is not economically viable from a public perspective. Benefit-cost analysis (BCA) can be used as a method to rank different projects or different alternatives for a single project all of which may have NPV of greater than zero and, therefore, are theoretically worthwhile. As explained by the Department of Transportation, “[i]n a capital-constrained situation, it is not possible to invest in every project with a positive NPV, and therefore a way to prioritize is required. The benefit-cost ratio is a measure of return on investment – ‘bang for the buck’.”\(^\text{17}\)

The duty to evaluate the economic viability of projects financed or authorized by government entities from a benefit-cost perspective is firmly ensconced in statutes, rules, regulations and guidance manuals for virtually every government agency at the federal, state, and local levels. For example, OMB’s Circular A-94 requirements apply to any analysis used to support government decisions to initiate, renew, or expand programs or projects which would result in a series of measurable benefits or costs extending for three or more years into the future.”\(^\text{18}\) Individual federal agencies have adopted the benefit-cost perspective in their individual regulatory frameworks.

For example, benefit-cost analysis and net present values are key components of EPA’s policy development and evaluation process.”\(^\text{19}\) U.S. Army Corps of Engineers (Corps) navigation and civil works projects are justified on the basis of their contributions to national economic development (NED), discussed below. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.”\(^\text{20}\) For the Corps to recommend federal cost share involvement in a project, the benefit-cost ratio must exceed 1.0.\(^\text{21}\) In Alaska, the benefit-cost perspective was recently

\(^{16}\) DOT. 2006. Note 14, Section 7.2.
\(^{17}\) Ibid.
\(^{18}\) OMB. Note 15, Section 4(a).
\(^{21}\) Principles and guidelines contained in Chapter 6, ER 1105-2-100, regarding National Economic Development (NED) Benefit Cost Analysis.
mandated in the Alaska Gasline Inducement Act (AGIA). AGIA is designed to expedite construction of a natural gas pipeline that —maximizes benefits to the people of the state.” In support of this purpose, the AGIA requires a strict NPV test for all projects as well as ranking of projects based on NPV.22

Thus, and the most important point made here, is that as decision makers at both the federal and state levels contemplate decisions to fund, authorize, or otherwise facilitate development of the Chuitna Coal Project those decisions must rest on a determination that project development is in the public interest through benefit-cost analysis and not narrow assessments of financial viability for potential investors. There are several key components to a rigorous analysis of net public benefits:

1.1.1 Incorporating both market and non-market costs and benefits

In a comprehensive net benefits analysis, everyone’s costs and benefits count. To make the process of determining whether or not a policy, program, or project creates net public benefits —all economic benefits and costs must be described and, where possible, quantified.23 These include costs and benefits that are easy to measure because they have direct effects in the market, as well as costs and benefits that are primarily non-market in nature but may be just as or even more significant economically. Thus, in the net public benefits analysis for the Chuitna Coal Project, it is critical for the Corps to consider all costs and benefits regardless of whether they are easy to measure market effects (i.e. consumer surplus for energy consumers) or more difficult non-market effects (i.e. health and other socio-economic costs of pollution or carbon emissions) regardless of who enjoys or incurs them.

Non-market effects are every bit as important economically, however, they do not manifest themselves in direct market transactions. Rather, they manifest themselves indirectly, through changes in home prices, recreational use patterns, subsistence hunting and fishing patterns, and expenditures on pollution control – for example – that are caused by changes in environmental quality associated with a policy, program, or project. Regulatory guidance provides a clear mandate to incorporate non-market effects into project analysis. For example, guidelines for analyzing federal infrastructure investments contains the following direction:

—all types of benefits and costs, both market and non-market, should be considered. To the extent that environmental and other non-market benefits and costs can be quantified, they shall be given the same weight as quantifiable market benefits and costs.”24

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22 Alaska Statutes (AS) Sec. 43.90.170.
24 Executive Order 12893, Principles for Federal Infrastructure Development.
As another example, the USFWS regulations for issuing incidental take permits require, in part, that the agency determine the “effects on other environmental values or resources” in deciding what level of NEPA analysis to apply. Likewise, in issuing permits for impacts to freshwater wetlands under its Clean Water Act Section 404 Program the Army Corps of Engineers must conduct a public interest determination that addresses all factors which may be relevant to the proposed wetland fill including:

— conservation, economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife values, flood hazards, floodplain values, land use, navigation, shore erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, considerations of property ownership and, in general, the needs and welfare of the people” (33 CFR § 320.4).

Clearly, many of these impacts are economic, and non-market in nature, and thus require application of non-market valuation techniques to estimate their magnitude. Fortunately, economists have at their disposal a wide range of tools for measuring non-market effects, including travel cost and random utility models, contingent valuation surveys, hedonic pricing models, benefits transfer, choice experiments, and replacement cost techniques.

One non-market cost of particular concern is the loss of passive use values for Chuitna’s exceptional wildlife habitat. Passive use values represent individual’s willingness to pay for protecting a resource, even if they may never use it in any way. With respect to wildlife, people are clearly willing to pay to protect species – some of them halfway around the world – that they may never even view. Contributions to international wildlife organizations are an example of how that willingness to pay is manifested. Passive use values for Alaska’s wilderness lands, wildlife refuges, and other intact landscapes extend to the entire U.S. population. For example, in Colt (2001) suggested that passive use values for 13.2 million acres encompassed by Bristol Bay Wildlife Refuges was in the order of $2.5 billion a year, or $3.5 billion in 2010 dollars. This translates into a value of $268 dollars an acre each year.

Passive use values can be an extremely important component of total economic value of a resource, and should not be overlooked. They can be quantified through contingent valuation surveys and choice experiments.

As the Corps is well aware of, the wildlife and fishery resources of the lands and waters affected by the Chuitna Coal Project are exceptional. The project area supports five terrestrial species with high public interest and ecological values including moose (Alces alces), brown bear (Ursus arctos), black bear (Ursus americanas), trumpeter swan (Cygnus buccinators) and lesser sandhill crane (Grus canadensis). Aquatic species with the same status include beaver (Castor canadensis), beluga (Delphinapturus leucas), chinook salmon

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(Oncorhynchus tshawytscha), coho salmon (Oncorhynchus kisutch), pink salmon (Oncorhynchus gorbuscha), and rainbow trout (Salmo gairdneri).27

The exceptional abundance and diversity of wildlife in the Chuitna Coal Project area suggests that passive use values are likely to be significant, and should not be excluded from the EIS and supporting benefit-cost analysis.

1.1.2 Ecosystem services

Ecosystem services are economic benefits provided by nature free of charge, and represent a unique class of non-market effect. The range of services is immense, and falls into four key categories: provisioning, supporting, cultural, and regulating.28 Some are more direct than others, such as the provision wild foods that support subsistence-based communities. Others are more indirect, such as carbon sequestration, that helps regulate global climate change. Ecosystem services are a significant source of economic value to nearby communities and the global economic system as a whole.

For example, in the Aleutians East Borough, a recent estimate put the weight of annual subsistence harvest of wild foods near 700,000 pounds.29 A replacement cost value of $7 a pound implies an annual harvest value of roughly $4,900,000.30 Colt (2001) prepared an ecosystem service assessment based on Costanza et al. (1997) suggesting ecosystem service values for Alaska marine and terrestrial ecosystems to range between $1 to over $76 per acre per year in 2010 dollars (Figure 1-1).31 The loss of these services provides one quantitative measure of non-market costs associated with developing lands in the Chuitna Coal Project area.

Because ecosystem service values generated by wild habitats in the project area are significant, the Corps economic analysis should address ecosystem service values in a quantitative fashion. In the NEPA context, there are two key approaches. First, because analysis of the no action alternative needs to be as in-depth as any of the action alternatives, the existing economic value of ecosystem services should be documented. Otherwise, the NEPA analysis will be arbitrarily skewed in favor of the action alternatives since the economic value of no action alternative will be assumed to be zero. Secondly, action alternatives that adversely affect ecosystem services create economic costs that should be tabulated. Again, failure to do so would skew the analysis in favor of the action alternatives.

30 The replacement cost method and per pound value estimate are described in “Subsistence In Alaska: 1994 Update,” Division of Subsistence, Alaska Department of Fish and Game. The 2009 value of the $5 per pound figure used in that study is $7.
Figure 1-1:

Costanza Methodology for Economic Value of Major Ecosystem Services
Applied to Alaska Lands and Waters

(millions of 1998 dollars per year)

<table>
<thead>
<tr>
<th>Biome</th>
<th>Millions of Acres in Alaska</th>
<th>Gas regulation</th>
<th>Climate regulation</th>
<th>Disturbance regulation</th>
<th>Water supply</th>
<th>Water quality</th>
<th>Erosion control and prevention</th>
<th>Soil formation</th>
<th>Nutrient cycling</th>
<th>Waste treatment</th>
<th>Pollution</th>
<th>Biological control</th>
<th>Habitat/Refugia</th>
<th>Total</th>
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<tbody>
<tr>
<td>Marine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Open Ocean</td>
<td>129.0</td>
<td>21.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>68.5</td>
<td>-</td>
<td>2.8</td>
<td>-</td>
<td>-</td>
<td>90.7</td>
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<td></td>
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<tr>
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<td>-</td>
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<td>7.4</td>
<td>-</td>
<td>-</td>
<td>310.9</td>
<td>-</td>
<td>3.2</td>
<td>0.7</td>
<td>-</td>
<td>322.2</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate / Boreal Forest</td>
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<td>-</td>
<td>54.3</td>
<td>1.2</td>
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<td>2.5</td>
<td>-</td>
<td>117.9</td>
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</tr>
<tr>
<td>Grass and rangeland</td>
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<td>0.5</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td>-</td>
<td>2.2</td>
<td>0.1</td>
<td>-</td>
<td>6.7</td>
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<tr>
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<td>0.7</td>
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<tr>
<td>Lakes &amp; Rivers</td>
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<td>125.9</td>
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<td>30.5</td>
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<td>-</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice/rock</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropland</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>0.1</td>
<td>-</td>
<td>-</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>512.8</td>
<td>28.1</td>
<td>54.3</td>
<td>216.5</td>
<td>324.6</td>
<td>299.9</td>
<td>2.2</td>
<td>6.3</td>
<td>377.4</td>
<td>291.3</td>
<td>2.0</td>
<td>10.4</td>
<td>14.6</td>
<td>1,627.6</td>
</tr>
<tr>
<td>Marine</td>
<td>147.2</td>
<td>21.4</td>
<td>0.0</td>
<td>7.4</td>
<td>0.0</td>
<td>0.0</td>
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<td>-</td>
<td>6.0</td>
<td>0.7</td>
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<td>54.3</td>
<td>209.1</td>
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<td>299.9</td>
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<td>2.0</td>
<td>4.4</td>
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<td>1,214.6</td>
</tr>
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</table>


There are many peer reviewed methods available to the Corps to put a price tag on both ecosystem service benefits provided by the no action alternative and the economic costs associated with ecosystem service degradation. These methods represent the “best available science,” and should be used. This is especially important because the Corps itself has been a leading proponent in revising its guidelines to incorporate ecosystem service values. As noted in the proposed revisions to the Corps procedures for analyzing water resource projects:

—Consideration of ecosystem services can play a key role in evaluating water resource alternatives. Using the best available methods in the ecological, social, and behavioral sciences to develop an explicit list of the services derived from an ecosystem is the first step in ensuring appropriate recognition of the full range of potential impacts of a given alternative. This can help make the formulation and the analysis of alternatives more transparent and accessible and can help inform decision makers of the full range

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of potential impacts stemming from different options before them. The second step is establishing the significance or value of changes in the quality or quantity of services over time, with and without the effects of proposed alternatives on ecosystem services.\footnote{See Council on Environmental Quality. 2010. Updated Principles and Guidelines for Water and Land Related Resources Implementation Studies at: http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG.}

The Corps can rely on many resources to apply state of the art methods for incorporating ecosystem service values in the EIS process.

1.1.3 Consumer surplus as the basis for benefit calculations

The basis for all benefit estimates should be changes in consumer and producer surplus, and not simple calculations of revenues, jobs, income and taxes generated from the sale of Chuitna coal. Consumer surplus is the excess amount that purchasers are willing to pay for a good or service over and above the market price (i.e., the area under the demand curve but above the price line). Consumer surplus serves as a measure of the social benefits of producing the good.\footnote{EPA. 2000. Note 19, Page 61.}

Policies that affect market conditions in ways that decrease prices will generally increase consumer surplus. This increase can be used to measure the benefits of the policy. As OMB recognizes, "consumer surplus provides the best measure of the total benefit to society from a government program or project."\footnote{OMB. Note 15, Section 4(a).}

Corps guidance recognizes consumer (and producer) surplus as the required basis for benefit calculations for projects that induce new commodity movements:

"New movement benefits are claimed when there are additional movements in a commodity or there are new commodities transported due to decreased transportation costs. The new movement benefit is defined as the increase in producer and consumer surplus, thus the estimate is limited to increases in production and consumption due to lower transportation costs" (ER 1105-2-100, 3-5).

With respect to coal, the presumed economic benefit is the consumer surplus households will receive associated with Chuitna coal relative to electricity derived from oil, gas, or renewables. This is a proper benefit from a public welfare perspective.

Analysts often confuse economic benefits with economic impacts. Economic impacts are the various local effects of spending and revenues. Economic impacts are described in terms of jobs, personal income, tax revenues, royalties, and rents generated by project spending and the revenues earned by market sales. The reason why these are not considered benefits from a welfare economics perspective is that they merely reflect a reallocation of spending and revenue away from other regions so that from a public perspective the net gain is often quite small or zero. So for example, investment by PacRim and its backers in Chuitna coal would come at the expense of investments in other regions or other energy projects (including renewables) that would confer a similar magnitude of economic impacts elsewhere.
The net economic effect of Chuitna relative to these other alternatives is difficult to discern, and so impacts are typically considered a separate kind of analysis and not suitable for use in a net public benefits or benefit-cost framework.

Decision makers often confuse benefits with impacts, erroneously comparing costs of development with economic impacts rather than benefits. This is not merely an esoteric consideration. Economic benefits are often far less than impacts, and so using impacts in a benefit-cost framework can significantly distort results. Thus, the Corps analysis should carefully distinguish between economic benefits in terms of the cost savings consumers receive (here and abroad) from the coal supplied by the Chuitna Mine and the regional economic impacts in Alaska. However, both benefits and impacts should be quantified with equal rigor using standard tools of economic analysis.

1.1.4 With and without framework

To insure that Corps water resources projects contribute net economic benefits to the nation, analysis must be conducted in what is known as a “with and without” framework. This framework requires that the Corps address net public benefits over the long term under two different scenarios: (a) the discounted stream of all market and non-market benefits and costs that can reasonably be expected in the absence of the project, and (b) the discounted stream of all market and non-market benefits and costs that would be generated with the project.

With and without analysis must take a long-term perspective. Typically, the Corps period of analysis extends to 100 years. According to the Corps NED guidance, “with and without project forecasts should be long run forecasts that avoid giving disproportionate weight to short run events.”

Thus, if a water resource project provides short run benefits to commodity producers but creates long term costs in the form of damaged marine ecosystems, the long run perspective will insure that the short-term gain is not over-emphasized.

The without-project scenario is the “most likely condition expected to exist over the planning period in the absence of the plan, including any known change in law or policy.” The without-project scenario provides the basis for estimating the benefits of the with-project scenario. In projecting economic conditions in the without-project scenario, the Corps is required to take into account which structural and non-structural measures may be taken by port agencies, other public agencies, or the transportation industry to accomplish the same objectives of the proposed plan as well as changes in technology that may have bearing on the need for the proposed project (Id.).

The without-project scenario has an important parallel in the National Environmental Policy Act (NEPA) process the Corps must complete for every water resource project. In

preparing environmental assessments or environmental impact statements pursuant to NEPA, the Corps must carefully consider the —no action‖ alternative. Moreover, consideration of this alternative must be completed with the same level of rigor applied to any of the action alternatives. Courts have consistently found that federal agencies must conduct —informed and meaningful‖ analysis of all alternatives, including no action, and to specifically address how the no action alternative affects environmental impacts and the cost-benefit balance.\footnote{38}{See, e.g. Bob Marshall Alliance v. Hodel, 852 F.2d 1223, 1228 (9th Cir. 1988); Alaska Wilderness Recreation and Tourism Association v. Morrison, 67 F.3d 723, 729-30 (9th Cir. 1995).}

The with-project scenario is the one expected to exist over the period of analysis if a project is undertaken. As in the without-project scenario, the Corps must project changes in technical, environmental, social, and economic conditions over the life of the project. Various alternative configurations of the project must also be modeled. Forecasts of with and without-project conditions must use the inventory of existing conditions as the baseline, and should consider direct, indirect, and cumulative effects on income, employment, output, population, exports, land use trends, demands for goods and services, and environmental conditions.\footnote{39}{WRC. 1983. Note 37, Page 4.}

Once completed, the Corps must compare with and without-project scenarios with the same set of criteria. In order to recommend federal approval of a project, the Corps must demonstrate that one of the with-project alternatives is the alternative that maximizes NED benefits. If the without-project scenario maximizes NED benefits, the Corps may not recommend federal approval.

1.1.5 Externalities

To complete a reasonably accurate NED account, the Corps must provide a full accounting of costs and benefits that would accrue to all parties regardless of whether they are directly affected by a proposed project. As explained by the Corps in its NED guidance manual, —[t]he NED principle requires that externalities be accounted for in order to assure efficient allocation of resources‖ (Id., 23). Tracking externalized costs is a standard requirement for evaluating all public expenditures.\footnote{40}{See, e.g. Office of Management and Budget, Circular A-94 at 6.} Consideration of externalities, whether they affect marketed or non-marketed goods and services, is a required component of all economic analyses supporting federal infrastructure investments.\footnote{41}{Principles for Federal Infrastructure Investments, Executive Order 12893 at Section 2(a).} Federal environmental justice guidelines require the Corps to pay particular attention to externalized costs of pollution when subsistence uses by Native Americans is at issue.\footnote{42}{Presidential Executive Order on Environmental Justice, Executive Order 12898 at Section 4-401.}

Marine and air pollution are examples of externalities that must be evaluated in the context of NED analysis. Navigation improvement projects sponsored by the Corps have the potential to both directly and indirectly contribute to greater amounts of marine pollution.
through dredging, construction of port infrastructure, greater throughput of marine traffic and cargo, and an overall increase in human use. Marine pollution can generally be divided into six major categories—oxygen demanding substances, suspended solids, pathogens, organic chemical toxicants, metal toxicants, and solid wastes.  

The presence of these substances in marine environment contaminates marine sediments, aquatic vegetation, benthic organisms, fish, shellfish, birds, mammals, and sea turtles (Id.). Contamination of marine ecosystems, in turn, translates into economic costs to humans in the form of adverse health effects, reductions in consumptive and non-consumptive use and enjoyment of marine environments, and adverse impacts to production activities in the seafood, wholesale trade, retail trade, travel, tourism, real estate, and housing sectors (Id., 94-95).

These costs are known as “externalized” costs since they are borne by individuals, communities, landowners and others who are not directly involved with Corps navigation projects. In fact, marine pollution is cited by the Corps as the “classic” example of an externality, and externalities of all kinds are “commonly encountered in many of the Corps’ missions” (Id., 22).

Externalized costs of Corps projects that lead to greater marine pollution can be quantified by any of the standard techniques for assessing both market and non-market effects of federal projects. However, the National Oceanic and Atmospheric Administration (NOAA) and the Department of Interior (DOI) have published special guidelines for how to assess the damage caused to natural resources from release of toxic substances. In a nutshell, these natural resource damage assessment (NRDA) procedures call for an accounting of damage that reflects the sum three basic components: (a) restoration costs; (b) compensable value; (c) assessment cost. Restoration costs are defined as the costs of restoration, rehabilitation, replacement, or acquisition of equivalent natural resources and services. Compensable value refers to lost use and non-use values to the public, and assessment costs refer to the costs of conducting the NRDA. Thus, when navigation project authorized by the Corps results in a risk of marine pollution, there are many methods available that can be used to assess the likely costs of such pollution under various scenarios.

One scenario that is often required by federal regulations is the “worst-case scenario,” such as a major oil spill. Worst-case scenarios were a required part of NEPA analysis through the mid-1980s, however, the regulations were changed to place limits on when the worst-case scenario must be analyzed. The Supreme Court has interpreted the present NEPA regulations to retain the duty to describe the consequences of a remote, but potentially severe impact in cases where scientific opinion suggests that it may occur. Regardless of whether a worst-

case scenario is required for all Corps projects, the Corps guidance on how to deal with risk and uncertainty suggests use of a worst-case scenario to establish an upper bound on unanticipated adverse outcomes: “a pessimistic or risk-averse decision maker may be interested in the maximum probable exposure or loss, or the worst-case scenario.”  

Air pollution is another externality often affected by Corps navigation projects because large vessels are often significant sources of pollutants in near shore environments. In fact, according to a recent study by the Natural Resources Defense Council —U.S. seaports are the largest and most poorly regulated sources of urban pollution in the county.” Sources of air pollution related externalities associated with the Chuitna Coal Project will be greenhouse gases, nitrous oxide, sulfur dioxide, and particulate matter — all which adversely affect climate and public health.

In December of 2009 the EPA issued an Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act: “the Administrator finds that greenhouse gases in the atmosphere may reasonably be anticipated both to endanger public health and to endanger public welfare.” It is clear that global warming caused by greenhouse gas emissions generates serious economic damage — estimated by one recent study to eventually reduce per capita consumption by 2100 by 20% at an annual cost of over $9 trillion. While there are no immediate regulatory restrictions related to coal, the fact that greenhouse gases are now formally recognized as air pollutants does require the Corps to address emissions associated with all phases of the Chuitna Coal Project and quantify the magnitude of negative externalities.

1.1.6 Uncertainty, risks, and sensitivity analysis

Navigation and other projects authorized by the Corps are planned in an environment replete with risk and uncertainty. As a result, the Corps is required to formally address risk and uncertainty in the context of NED analysis, and to not characterize the benefits and costs of its projects in certain terms. Mischaracterizing uncertain outcomes as certain can result in serious overstatements of project benefits. Likewise, failing to acknowledge and quantify risks can lead to serious understatements of expected project costs.

The Corps defines risky situations as —those in which the potential outcomes can be described in reasonably well known probability distributions.” For example, the probability of floods and severe storms occurring within a specified time frame is described reasonably well by a known probability distribution. Likewise, the probability of accidental spills of oil

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50 Federal Register Volume 74, No. 239, Tuesday, December 15th, 2009.
or other hazardous substances from specific types of vessels or port facilities can be calculated from historical records.

In contrast, when potential outcomes cannot be described in objectively known probability distributions they are labeled uncertain outcomes. Uncertainty permeates environmental planning. With respect to navigation, uncertainty clouds commodity demand and price forecasts, predictions of required amounts of dredging, reliability projections for navigation structures and port facilities, transit times for commercial traffic, and many other factors that have bearing on project costs and benefits. Many projected benefits and costs of navigation projects do not have known probability distributions and, thus, are uncertain.

Expected value analysis is one method the Corps has at its disposal to incorporate risk into its NED analyses. Stated simply, expected value analysis requires multiplication of cost and benefit estimates, either point estimates or ranges, by the probability of their occurrence. Expected value analysis, then, deflates benefit and cost estimates to reflect the inherent ambiguity about their future values. Expected value analysis is a rather crude way to incorporate risk, since it does not tell us anything about the specific risk factors associated with various alternatives. Because of this, the Corps has developed much more sophisticated methods to address both risk and uncertainty that fall under the general heading of “risk analysis,” which has three basic components:

1) risk assessment, which involves the analysis of the technical aspects of the problem to determine uncertainties and their magnitudes;
2) risk communication, which deals with conveying information about the nature of risks to all interested parties, and;
3) risk management, which involves decisions on how to handle risks.

The National Research Council has also outlined ways in which the Corps should go about incorporating risk and uncertainty into decisions. NRC describes four “state of the art” methods including sensitivity analysis, Monte Carlo analysis, scenario analysis, and the process of finding “robust” alternatives that are immune to the volatility of benefit and cost estimates caused by uncertain parameters. Thus, there are a variety of widely endorsed analytical tools the Corps can use to fulfill its obligations to incorporate risk and uncertainty into project planning.

1.2 Net Public Benefits and the Regulatory Framework for Chuitna

The statutes, regulations, and rules governing analysis of the Chuitna Coal Project underscore the importance of the net public benefits framework in general as well as many of the specific components of a proper analysis, such as benefit-cost analysis, addressing

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54 Ibid.
externalities, non-market benefits and costs, and the with and without framework. For example:

1.2.1 Water Resources Development Act

As previously noted, Corps navigation and civil works projects are justified on the basis of their contributions to national economic development (NED), which is analogous to net public benefits. This requirement is set forth in the Water Resources Development Act (WRDA), the Water Resources Council (WRC) regulations implementing the Act, and Corps guidance manuals. According to the Water Resources Council (1983):

"Contributions to national economic development are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed."\(^{58}\)

NED analysis provides the basis for identifying appropriate benefits and costs associated with Corps flood control, navigation, hydroelectric, water supply or environmental projects to include in subsequent benefit cost analyses of these projects.\(^{59}\) Benefit cost analysis is used to determine whether national economic development effects of a project are positive or negative. In other words, benefit cost analysis is undertaken to assure that the value of the outputs exceeds the value of the inputs.

1.2.2 Principles and Guidelines for Water and Related Land Resources Implementation Studies

The WRDA and NED analysis are implemented under procedures set forth in the Water Resources Council’s Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. The first set of “Principles” was issued in September 1973 to guide the preparation of river basin plans and to evaluate federal water projects. Following a few attempts to revise those initial standards, the current principles and guidelines went into effect in March 1983. As established above, the Principles already provide unambiguous direction for the Corp to conduct economic analysis under the net public benefits framework. This mandate is being amplified and made even more explicit in revisions to the Principles that will likely be completed before the Corps begins formal economic analysis of the Chuitna Coal Project.

In the reauthorized Water Resources Development Act of 2007, Congress instructed the Secretary of the Army to develop a new Principles and Guidelines for the U.S. Army Corps of Engineers (section 2031). In an effort to modernize the approach to water resources development, the Obama Administration is expanding the scope of the Principles and Guidelines to cover all federal agencies that undertake water resource projects, not just the four agencies (i.e., U.S. Army Corps of Engineers, Bureau of Reclamation, Natural Resources

\(^{58}\) WRC. 1983. Note 37, Page 1.  
Conservation Service and the Tennessee Valley Authority) which are subject to the current Principles and Guidelines. The revised Principles include a number of important changes that modernize the current approach to water resources development in this country and which underscore the importance of economic analysis under the net public benefits standards.\(^\text{60}\) As explained by the Council on Environmental Quality, the revisions address two key considerations: maximizing net public benefits broadly, and incorporating both monetary and non-monetary benefits:

- **Achieving co-equal goals:** The Administration’s proposal reiterates that federal water resources planning and development should both protect and restore the environment and improve the economic well-being of the nation for present and future generations. While the 1983 standards emphasized economic development alone, the new approach calls for development of water resources projects based on sound science that maximize net national economic, environmental, and social benefits.

- **Considering monetary and non-monetary benefits:** The revised Principles and Guidelines shift away from the earlier approach to project selection. Specifically, this revised version will consider both monetary and non-monetary benefits to justify and select a project that has the greatest net benefits—regardless of whether those benefits are monetary or non-monetary. For example, the monetary benefits might capture reduced damages measured in dollars while the non-monetary benefits might capture increased fish and wildlife benefits, or biodiversity.

### 1.2.3 National Environmental Policy Act

In addition to formal benefit-cost analysis (BCA) required by the WRDA and its implementing Principles all Corps water resource projects that may significantly affect environmental quality must be accompanied by an environmental impact statement pursuant to the National Environmental Policy Act (NEPA, 42 U.S.C. § 421 et seq.) While NEPA by itself does not generally require federal agencies to conduct a formal cost-benefit analysis, the Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR § 1502.23) set out the requirements for incorporating any BCA that may be prepared into the NEPA process. In addition, NEPA and its implementing regulations guide other components of the economic analysis including establishing a purpose and need, addressing cumulative impacts, and rigorous consideration of the “no action” alternative.

**Incorporating BCA into the NEPA process**

The CEQ regulations state that, if a BCA relevant to the choice among environmentally different alternatives is being considered for a proposed action under NEPA, it shall be incorporated into the EIS as an aid in evaluating the environmental consequences of the project.\(^\text{61}\) Furthermore, the regulation requires that any BCA must discuss—“the relationship between that analysis and any analyses of unquantified environmental impacts, values, and amenities.” The regulation also provides that, although the weighing of the merits

\(^{60}\) See CEQ’s website at: http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG.

\(^{61}\) 40 CFR § 1502.23.
and drawbacks of the various alternatives need not be displayed in a monetary cost-benefit analysis, an EIS must at least indicate those considerations, including factors not related to environmental quality, which are likely to be relevant and important to a decision.”

The WRC regulations operationalize the CEQ requirement with respect to benefit cost analysis (BCA) prepared for water resource projects undertaken by the Corps and other federal agencies. The WRC regulations require the Corps to maintain four separate sets of accounts which enable Corps decision makers to compare economic values and impacts that are not included in the formal BCA but which, none the less, may have significant bearing on a project’s feasibility with those that are included.62 The four accounts include:

- The National Economic Development (NED) account. The NED account describes that part of the NEPA human environment, as defined in 40 CFR §1508.14, that identifies beneficial and adverse effects on the economy.

- A Regional Economic Development (RED) account. The RED account registers changes in the distribution of regional economic activity that result from each alternative plan. Two measures of the effects of the plan on regional economies are used in the account: regional income and regional employment. The regions used for RED analysis are those regions with in which the plan will have particularly significant income and employment effects.

- An Environmental Quality account (EQ) account. The EQ account is a means of displaying and integrating into water resources planning that information on the effects of alternative plans on significant EQ resources and attributes of the NEPA human environment, as defined in 40 CFR § 1507.14, that is essential to a reasoned choice among alternative plans. Significant means likely to have a material bearing on the decision making process.

- An Other Social Effects (OSE) account. The OSE account is a means of displaying and integrating into water resource planning information on alternative plan effects from perspectives that are not reflected in the other three accounts. The categories of effects in the OSE account include the following: urban and community impacts; life, health, and safety factors; displacement; long-term productivity; energy requirements and energy conservation.

Importantly, all four accounts are needed to satisfy the CEQ NEPA obligations: “[t]hese four accounts encompass all significant effects of a plan on the human environment as required by the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq.).”63

Thus, the proper manner in which to incorporate BCA findings into an EIS is to include the BCA in the NED account, and then compare its findings and values with those reported by the other three accounts. In this way, the Corps is able to meet its obligations to

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62 WRC. 1983. Note 37, Pages 8-12.
63 Ibid, Page 8.
discuss the relationship between NED analysis and any analyses of unquantified
environmental impacts, values, and amenities or other considerations not related to
environmental quality as required by 40 C.F.R. §1503.23. Failure to do this gives too much
emphasis to the BCA in the decision making process.

**Establishing a purpose and need**

The purpose and need section is the most critical section of an EIS. CEQ regulations
require federal agencies to “[s]pecify the underlying purpose and need to which the agency is
responding in proposing the alternatives including the proposed action” (40 CFR § 1502.13).
A precise definition of the purpose and need establishes “why the agency is proposing to
spend large amounts of taxpayers' money while at the same time causing significant
environmental impacts.”

A clear, well-justified purpose and need section demonstrates why expenditure of public funds and permits or authorizations for natural resource disturbances are
necessary and worthwhile and why the project is being prioritized relative to other needed
land management, transportation, or infrastructure projects.

In addition, “although significant environmental impacts are expected to be caused by
the project, the purpose and need section should justify why impacts are acceptable based on
the project's importance.” As with other aspects of the Corps economic analysis,
establishing purpose and need must identify the public benefits (i.e. NED benefits) associated
with the project, and not simply report why the project is important to a small number or even
a single private entity.

**Cumulative impacts**

The CEQ regulations require agencies to consider three types of actions when
preparing an EIS: 1) “connected actions,” which means they are closely related and therefore
should be discussed in the same impact statement; 2) “cumulative actions,” which when
viewed with other proposed actions have cumulatively significant impacts and should
therefore be discussed in the same impact statement; and 3) “similar actions,” which when
viewed with other reasonably foreseeable or proposed agency actions, have similarities that
provide a basis for evaluating their environmental consequences together, such as common
timing or geography.

Federal agencies must also consider three types of potential environmental impacts or
“effects” of their proposed actions and programs in the EIS process: direct, indirect, and
cumulative. The CEQ regulations define “effects” as being synonymous with “impacts.”

Direct effects are those caused by the action that occur at the same time and place. Indirect
effects are those caused by the action that are later in time or farther removed in distance, but
are still reasonably foreseeable. Indirect effects include the “growth inducing” effects and
other effects related to induced changes in the pattern of land use, population density or

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65 Ibid.
66 40 CFR § 1508.25(a).
67 40 CFR § 1508.25(c).
growth rate, and related effects on air and water and natural systems, including ecosystems. Court decisions construing NEPA have recognized that federally-assisted projects which contribute to urban sprawl are required to evaluate the growth inducing effect of additional development.\textsuperscript{68}

Pursuant to 40 C.F.R. §1508.25(c)(3), an environmental impact statement must consider a proposed project’s “cumulative impact.” 40 C.F.R. §1508.7 defines cumulative impacts as the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.” Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.”

Court decisions have uniformly construed NEPA’s cumulative effects requirement to require Federal agencies to conduct a comprehensive analysis of the impact of connected or cumulative actions in order to prevent agencies from dividing one project into multiple individual actions each of which has an insignificant environmental impact, but which collectively have a substantial impact.\textsuperscript{69} As other Court decisions have recognized, at least some Federal agencies contributing to urban sprawl have a specific duty under their own NEPA regulations to “group together” and evaluate as a single project, all individual activities which are related on either a geographical or functional basis, or are logical parts of a composite of contemplated actions.\textsuperscript{70}

The CEQ regulations recognize that evaluation of the “significance” of major Federal actions involves consideration of context as well as the intensity of potential environmental impacts. This means that the significance of proposed actions must be analyzed in several contexts, including the affected region” and the “locality” of those actions (40 CFR §1508.27(a)). The CEQ regulations also suggest that, when preparing EIS’s on broad federal actions (including proposals by more than one agency), agencies “may find it useful” to evaluate the proposal(s) on a geographical basis, including actions occurring in the same general location, such as body of water, region, or metropolitan area” (40 CFR §1502.4(c)(1)).

In recent decisions construing NEPA’s requirement that agency’s evaluate the cumulative impacts of a proposed project, the Ninth Circuit has held that an environmental impact statement must “catalogue adequately past projects in the area” and provide a “useful analysis of the cumulative impact of past, present, and future projects.”\textsuperscript{71}

\textsuperscript{68} See e.g., City of Davis v. Coleman, 521 F.2d 661 (9th Cir. 1995) (highway construction); Carmel-by-the-Sea v. U.S. Dept. of Transportation, 123 F.3d 1142 (9th Cir. 1997) (highway construction); Morongo Band of Mission Indians v. FAA, 161 F.3d 569 (9th Cir. 1998) (airport expansion).

\textsuperscript{69} See e.g., National Wildlife Federation v. FERC, 912 F.2d 1471 (D.C. Cir. 1990); Natural Resources Defense Council, Inc. v. Hodel, 865 F.2d 286, 297-98 (D.C. Cir. 1988).


\textsuperscript{71} See e.g., Northwest Environmental Advocates v. National Marine Fisheries Service, 2006 WL 2422681 (9th Cir. 2006) (noting that the Army Corps of Engineers was required to evaluate the cumulative impacts of a channel deepening project, including disposal of dredged material at a deepwater site, on sediment availability and transport in light of existing projects, and coastal erosion, as well as salinity in light of past actions) citing,
Given these requirements, it is clear that any discussion of economic impacts associated with the Chuitna Coal Project must consider not only the direct costs and benefits associated with the surface coal mine and associated support facilities, mine access road, coal transport conveyor, personnel housing, air strip facility, logistic center, and coal export terminal but also include an analysis of effects associated with increased access to the area, potential for mine expansion, separate future mining activities and other potential induced or connected future actions made possible by the Project’s infrastructure.\textsuperscript{72}

**Rigorous consideration of the “no action” alternative**

As previously noted, the stream of market and non-market benefits associated with the Project must be compared in a “with and without” context. Importantly, this requires a detailed consideration and valuation of all of the existing beneficial uses of the project area, including subsistence use, passive use values for native wildlife, carbon sequestration benefits, fish production, and other ecosystem services. By doing so, alternatives in the EIS are not improperly skewed towards the action alternatives and the economic benefits of leaving the Chuitna Coal Project area intact are identified and quantified where possible.

### 1.2.4 Clean Water Act

The Clean Water Act regulates several aspects of the Chuitna Coal Project. The duty to consider economic impacts broadly, from the net public benefits framework is found in multiple sections. For example, Section 404(b)(1) sets forth guidelines for specification of disposal sites for dredged or fill material. With limited exceptions, no discharge of dredged or fill material is permitted which will cause or contribute to significant degradation of the waters of the United States. Guidelines for findings of significant degradation related to the proposed discharge are based upon appropriate factual determinations, evaluations, and tests required by other subparts. Taken together, effects contributing to significant degradation considered individually or collectively, include:

- Significantly adverse effects of the discharge of pollutants on human health or welfare, including but not limited to effects on municipal water supplies, plankton, fish, shellfish, wildlife, and special aquatic sites.

- Significantly adverse effects of the discharge of pollutants on life stages of aquatic life and other wildlife dependent on aquatic ecosystems, including the transfer, concentration, and spread of pollutants or their byproducts outside of the disposal site through biological, physical, and chemical processes;

\textsuperscript{72} These three cumulative actions were identified in the Scoping Report, page 16.
• Significantly adverse effects of the discharge of pollutants on aquatic ecosystem diversity, productivity, and stability. Such effects may include, but are not limited to, loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate nutrients, purify water, or reduce wave energy; or

• Significantly adverse effects of discharge of pollutants on recreational, aesthetic, and economic values.

Clearly, the duty to consider loss of ecosystem service values and other market and non-market effects envisioned by the net public benefits standard are reiterated by the plain language of these Clean Water Act regulations.

1.2.5 Fish and Wildlife Coordination Act (FWCA)

The Chuitna Coal Project will require diversion of a substantial amount of freshwater for dust control, processing of wastes, tailings impoundments, and operations. Under the FWCA, the application must obtain an authorization from the U.S. Fish and Wildlife Service for any water diversions. As part of that authorization, the USFWS must estimate wildlife benefits or losses. Wildlife benefits associated with mitigation measures targeted at improved wildlife resources must be compared with the costs of implementing these measures. To be complete, non-market valuation – including estimation of passive use benefits – is an important part of this analysis since the majority of wildlife benefits are non-market in nature.

1.2.6 Solid waste management permit

The mine and infrastructure components of the Chuitna Coal Project could require solid waste disposal or management permits. The Alaska Department of Environmental Conservation is responsible for issuing waste permits in compliance with 18 AAC 60. These regulations envision a social benefit-cost test to demonstrate that the benefits of constructing and operating the source outweigh its externalized social and environmental costs. An important part of the analysis supporting the permit includes demonstration that the benefits of construction, operation, or modification of the stationary source will significantly outweigh the environmental and social costs incurred. To secure a waiver of applicable regulations, applications must demonstrate that:

(1) compliance with the identified provision would cost significantly more than the value of the environmental benefit, public health risk reduction, and nuisance avoidance that could be achieved through compliance with the identified provision; or

73 Fish and Wildlife Coordination Act, 16 USC § 661-666c
74 Ibid, Section 3.
75 The Final Environmental Impact Statement for the Diamond Chuitna Coal Project noted that solid waste disposal permits would be required for the mine and housing units. See U.S. Environmental Protection Agency.
76 18 Alaska Administrative Code 60
(2) the proposed alternative action will provide equal or better environmental protection, reduction in public health risk, and control of nuisance factors than compliance with the identified provision.\textsuperscript{77}

These provisions underscore the necessity of valuing largely non-market benefits and costs associated with environmental protection, public health risk and nuisance factors.

1.2.7 Marine, Protection, Research, and Sanctuaries Act Section 103(MPRSA)

Dredged material from development of the Ladd Landing Facility and deep draft channels accessing the export facility may be dumped offshore. As such, provisions of the MPRSA may apply. Permits for ocean dumping must be obtained from the U.S. Army Corps of Engineers using environmental criteria developed by the Environmental Protection Agency. The criteria must ensure that such dumping will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities.\textsuperscript{78} In addition, the criteria must consider the externalized costs of the proposed dumping and specifically include the effect of such dumping on human health and welfare, including economic, esthetic, and recreational values.\textsuperscript{79}

1.2.8 Dam safety certification

Tailings impoundment dams associated with the Chuitna Coal Project would require dam safety certification by the Alaska Department of Natural Resources (ADNR). Issuance of the certificate requires ADNR to classify the dam into one of three hazard types. As part of the hazard classification process, ADNR must consider potential losses or damage to human life, health, infrastructure, commercial and residential properties, anadromous fish and other economic resources should the dam fail.\textsuperscript{80} A consideration of these potential costs should be part of the overall risk assessment for the project.

1.2.9 Alaska Coastal Management Plan consistency review

Because the Chuitna Coal Project lies within the coastal zone and affects offshore areas, estuaries, and wetlands, it is subject to an Alaska Coastal Management Plan consistency review led by ADNR. In the Coastal Zone Management Act (CZMA), Congress created a federal-state partnership for management of coastal resources. Section 307 of the CZMA requires that federally licensed or permitted activities be consistent with state coastal management policies (e.g., land use planning statutes, marine spatial planning, and water quality standards. A consistency determination is the process used to implement this requirement for federal permits and licenses.

Federal consistency reviews are not performed by one single agency. Rather ADNR’s Department of Ocean and Coastal Management coordinates a collaborative process review.

\textsuperscript{77} Ibid. at 131.
\textsuperscript{78} Marine Protection, Research, and Sanctuaries Act. 16 USC § 1431 et seq. and 33 USC §1401 et seq.
\textsuperscript{79} Ibid. at 5.
\textsuperscript{80} 11 Alaska Administrative Code 93.157.
involving Alaska’s natural resource agencies. Participants in the coastal consistency review process include the applicant, state agencies, the affected coastal district(s), interested members of the public, and relevant federal agencies. As part of the review process, ADNR and its collaborators must determine whether or not the Project impairs management of coastal and offshore habitats and includes mitigation measures that adequately protect competing economic uses. For example, both offshore areas and estuaries must be managed-to avoid, minimize, or mitigate significant adverse impacts to competing uses such as commercial, recreational, or subsistence fishing. Quantifying both market and non-market values associated with these competing uses and predicting how the Project would alter such values is critical for determining whether or not the Project surpasses the significance threshold.

1.3. Specific Recommendation for the Economic Analysis

Based on the foregoing, the scope and substance of the economic analysis the Corps will be preparing for the Chuitna Coal Project should include the following:

- Net public benefits should be the framework adopted for the analysis. The Corps existing National Economic Development (NED) procedures and guidance should be used in combination with guidance applicable to all federal agencies such as those published by Office of Management and Budget as well as economic analysis guidance contained in the numerous statutes, regulations, and rules governing each of the permitting activities associated with the project (Appendix 1-1).

- Both market and non-market benefits and costs should be described and quantified to the extent practicable based on the best available sources of information and methods. This includes quantification of externalities and the benefits of ecosystem services.

- Original valuation studies should be implemented to develop rigorous values to assign to changes in passive use values, subsistence use, loss of fisheries, carbon emissions damage, air quality damages, and other non-market effects. The costs of such studies are typically a small fraction on what the Corps will spend on other aspects of its feasibility analysis.

- The Chuitna Coal Project is ideal for demonstration of how ecosystem service values can be incorporated into regulatory analysis. As such, we recommend that the Corps and other partners on the USDA Environmental Markets Team adopt this project as pilot.

- In accordance with net public benefits analysis standards and NED guidance, potential benefits of the Chuitna Coal Project should be described and quantified in terms of changes in consumer and producer surplus. These benefits should be distinguished from economic impacts, which include jobs, income, tax revenues, and coal revenues. Economic benefits, not impacts, should be used in the formal benefit-cost analysis.

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81 11 Alaska Administrative Code 112.300 (b)1-2.
In the sections that follow, we present a preliminary analysis of net public benefits in order to provide a sense of what the Corps will likely find once it completes a sufficient analysis with detailed site-specific information provided by PacRim. We begin with an analysis of the potential NED and RED benefits associated with the project in terms of net revenues from sale of Chuitna Coal on the Asian markets as well as employment, income, and regional tax benefits in Section 2. We then discuss financial and non-market costs in Section 3. Benefits and costs are combined in Section 4 to generate initial estimates of potential net public benefits.
Appendix 1-1: Regulatory and Permitting Requirements for the Chuitna Coal Project

<table>
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<tr>
<th>Regulatory process</th>
<th>Agency</th>
<th>Chuitna Coal Mine</th>
<th>Chuitna Infrastructure</th>
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## Appendix 1: Regulatory and Permitting Requirements for the Chuitna Coal Project (Page 2)

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### Appendix 1: Regulatory and Permitting Requirements for the Chuitna Coal Project (Page 3)

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## Appendix 1: Regulatory and Permitting Requirements for the Chuitna Coal Project (Page 4)

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<td>Special area permit(s)</td>
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<td>Scientific collection permit(s)</td>
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<td>Fish resource permits(s)</td>
<td>ADF&amp;G</td>
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</table>

**Sources:**

Section 2: National and Regional Economic Development Benefits

As set forth in Section 1, the Corps has operationalized the concept of net public benefits in procedures the agency uses to evaluate the contribution of water resource projects to national economic development (NED). In other words, net public benefits and NED are synonymous. NED analysis represents the agency’s best scientific methods. The components of NED analysis are established by the 1983 Water Resource Council (WRC) Principles and Guidelines.\(^{82}\) Civil works projects for which NED analysis is required include navigation, flood damage reduction and ecosystem restoration, as well as for storm damage prevention, hydroelectric power, recreation, and water supply.\(^{83}\) An analysis of NED benefits and costs is thus required for the coal export facility proposed at Ladd Landing since this falls under the definition of a general navigation facility. However, since the Chuitna Coal conveyor, associated infrastructure, and mine would not exist without development of Ladd Landing and vice versa the entire Chuitna Coal Project must be considered as an integrated plan to which NED analysis is applied.\(^{84}\)

In addition to NED benefits, civil works projects must disclose regional economic development (RED) impacts. The RED analysis registers changes in the distribution of regional economic activity that result from the proposed plan. Two measures of the effects of the plan on regional economies are used: regional income and regional employment. In addition, RED analysis often considers effects on state and local tax collections. The regions used for RED analysis are those regions within which the plan will have particularly significant income and employment effects.\(^{85}\)

As of this writing, neither the Corps nor PacRim has submitted detailed cost and expenditure data or revenue projections from the sale of Chuitna coal into the official project record. Thus, to generate preliminary estimates NED and RED benefits and impacts, we rely on other published sources of information.

2.1 NED Benefits

General navigation features of harbor or waterway projects are channels, jetties or breakwaters, locks and dams, basins or water areas for vessel maneuvering, turning, passing, mooring or anchoring incidental to transit of the channels and locks. Also included are dredged material disposal areas and shoreline facilities to facilitate the transfer of commodities from land

\(^{82}\) WRC. 1983. Note 37.
\(^{83}\) Engineering Regulation (ER) 1105-2-100, page 1-1.
\(^{84}\) WRC (1983, p. 17) tiers its definition of the NED planning area to the National Environmental Policy Act: “The NED account describes that part of the NEPA human environment, as defined in 40 CFR 1508.14, that identifies beneficial and adverse effects.” NEPA, in turn, requires analysis of all “connected actions” together in a single environmental impact statement. Connected actions are “actions that are closely related and therefore should be discussed in the same impact statement” (40 CFR § 1508.25(a)).
\(^{85}\) WRC. 1983. Note 37.
The Corps describes four general categories of NED benefits associated with the development of general navigation facilities. These include:

1. Cost reduction benefits for commodities for the same origin and destination and the same mode of transit thus increasing the efficiency of current users.
2. Shift of mode benefits for commodities for the same origin and destination providing efficiency in waterway or harbor traversed.
3. Shift in origin and destinations that would provide benefits by either reducing the cost of transport, if a new origin is used or by increasing net revenue of the producer, if a change in destination is realized.
4. New movement benefits are claimed when there are additional movements in a commodity or there are new commodities transported due to decreased transportation costs.
5. Induced movement benefits are the value of a delivered commodity less production and transportation costs when a commodity or additional quantities of a commodity are produced and consumed due to lower transportation costs.

Chuitna coal represents a new commodity on the market and a new origin and thus NED benefit categories 4 and 5 apply. Development of the Ladd Landing export facility will make development of the mine possible, presumably because alternative transport options are not currently available or cost prohibitive (i.e. constructing new roads or rail lines). Development of the Ladd Landing facility can be seen, then, as a decrease in transportation costs for Alaska coal in general or a facility that lowers transportation costs to the point where new commodity (Chuitna coal) shipments become possible. Regardless, the calculation of NED benefits involves quantification of three basic variables:

a. The likely selling price of Chuitna coal in the Asian market.
b. The delivered cost of Chuitna coal taking into account capital, operating, and maintenance costs associated with all project components and transportation costs to Asia.
c. The difference between the cost of transportation with the project and the maximum cost the shipper would be willing to pay.

Benefit category 4 is further refined by Corps regulations to include increases in consumer and producer surplus. Consumer surplus was discussed in Section 1 and would be difficult to calculate in this analysis since neither the specific end users of Chuitna coal nor the energy alternatives available to those users has been identified in the project record. Thus, it is not possible to calculate the cost savings to consumers associated with consumption of Chuitna coal relative to other sources of energy. Producer surplus is calculated as the area above an industry supply curve but below the price line. Producer surplus can also be calculated for an individual source of supply if marginal costs are known at various levels of production. This information, however, is also not available in the Chuitna Project record. A good proxy for produce surplus, however, is simply net revenues, calculated by subtracting the second term from the first (a – b). This also meets the literal terms of the NED benefit definition for category 5.

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86 Engineering Regulation (ER) 1105-2-100, page 3-2.
87 Engineering Regulation (ER) 1105-2-100, page 3-5.
Corps guidance further refines benefit category 5 to include the third variable \( c \), which appears to be different in both concept and calculations than the former two. However, since the maximum cost a shipper would be willing to pay would, in fact, be a function of the difference between delivered cost (including production and transportation) and expected sale revenues, it is safe to simply focus on the first two variables.

2.1.1 Gross revenues from Chuitna coal sales in the Asian market

As of this writing, the project record does not specify a final destination for Chuitna coal. However, since inception of the Chuitna Coal Project it has been widely assumed that the end use of Chuitna coal would be for generation of commercial and residential electricity supply by coal-fired plants in China or other Asian nations. According to a recent article that appeared in the Alaska Journal of Commerce: “A dock jutting two-miles out into the Inlet would shuttle the coal onto 1,200-foot freighters several times a week. The giant vessels would travel through Shelikof Strait and along the Aleutian Chain to deliver the coal to Asian power plants.” Indeed, the state’s only coal mine in operation – Usibelli – exports a significant share of its production to South Korea. Japan is also testing the feasibility of coal imports. Thus, for purposes of our analysis, it is reasonable to assume that the basis for gross revenue projections should be the selling price of Chuitna coal in Asian markets over the 25 year project life. To estimate the likely selling price, we examine current and historical import prices at major ports as well as future forecasts based on International Energy Agency data.

Current and historical price trends

The most authoritative source for current coal export and import prices is the International Energy Agency’s quarterly publication “Coal Price Trends.” The publication provides historical export and import price data for ports in all major coal producers including a number of ports in Japan, Korea, and China. The data provide historical import price data based on cost, insurance, and freight (CIF) prices, and export data in terms of freight on board (FOB) prices. The distinction is as follows, according to the Globe Express Services Dictionary of International Trade:

- **Cost, Insurance and Freight (CIF)** – An international trade term of sale in which, for the quoted price, the seller/exporter/manufacturer clears the goods past the ship’s rail at the port of shipment (not destination). The seller is also responsible for paying for the costs associated with transport of the goods to the named port at destination. However, once the goods pass the ship’s rail at the port of shipment, the buyer assumes responsibility for risk of loss or damage as well as any additional transport costs. The seller is also responsible for procuring and paying for marine insurance in the buyer’s name for the shipment. The Cost and Freight term is used only for ocean or inland waterway transport.

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90 http://www.speedycargo.com/resource-center/cif-vs-fob
- **Free On Board (FOB)** – An international trade term of sale in which, for the quoted price, the seller/exporter/manufacturer clears the goods for export and is responsible for the costs and risks of delivering the goods past the ship’s rail at the named port of shipment. The Free On Board term is used only for ocean or inland waterway transport.

The distinction is not dramatic, but important is that there is a lag time between official reporting of CIF and FOB prices, with the latter taking longer to “catch up” in official statistics.

In Figure 2-1, we show historical CIF and FOB prices in $US (2010) per metric ton for the largest Asian coal shipments from Australia and Canada to Japan, China, and Korea. These shipments represent the lion’s share of Asian imports, and so are indicative of what shipments from Chuitna would need to sell for in order to stay competitive. Price data reflect a rather long period of stability from 1994 to 2004 in the $30-$40 price range, a dramatic spike to nearly $130 between 2004 and 2008 and a dramatic drop thereafter. Currently, mean prices are hovering in the low $90s.

**Figure 2-1:**

To get a sense of gross revenues from the sale of Chuitna coal in the Asian market, we need to project these prices forward. In order to do this, a number of demand and supply factors need to be taken into account such as the potential for major investment in renewable energy, China’s recent entry into coal export markets, and the relative price of coal with respect to oil. There are no publicly available sources of data projecting Asian import price data; however, we can nonetheless model several scenarios by combining coal price scenarios published by the U.S. Energy Information Administration (EIA) with coal demand projections published by International Energy Agency (IEA) in its regular World Energy Outlook. Each of these sources
provides a similar set of future scenarios. In its latest forecasts, the EIA models four separate scenarios: (1) high coal cost; (2) high oil price; (3) a reference case, and (4) low coal cost. Prices are dependent on assumptions about coal production (which varies across the EIA cases under different assumptions about the costs of producing and transporting coal), the outlook for economic growth, and the outlook for world oil prices. EIA also recognizes that government interventions to reduce greenhouse gas emissions could play a significant role on coal production and prices, though no scenario explicitly addresses this.

Assumptions about economic growth primarily affect the projections for overall electricity demand, which in turn determine the need for coal-fired generation. In contrast, assumptions about the costs of producing and transporting coal primarily affect the choice of technologies for electricity generation, with coal capturing a larger share of the U.S. electricity market in the Low Coal Cost case and a smaller share in the High Coal Cost case. In the High Oil Price case, higher oil prices stimulate the demand for coal-based synthetic liquids, leading to a substantial expansion of coal use at coal to liquid plants. Production of coal-based synthetic liquids totals 919,000 barrels per day in 2035 in the High Oil Price case, nearly four times more than in the Reference case.

**Figure 2-2:**

![Asian Steam Coal Import Price Scenarios](image)
Coal production in the reference case increases by 6% by 2030, whereas the alternative cases show changes ranging from a decrease of 7% to an increase in 16%. These variations in production, in turn, underlie EIA coal price projections 2010 to 2040 as follows: +72.22% (High Coal Cost); +5.56% (High Oil Price); -1.39% (Reference Case); -38.89% (Low Coal Cost). Because the EIA did consider international factors in its analysis, it is useful to project these four scenarios on Asian import prices. Figure 2-2 presents four price scenarios based on these percentage changes for Asian coal imports beginning with the baseline price of $91.93 in 2010. By 2040, coal prices across the scenarios range from a high of $158 to a low of $57 per metric ton.

Corroboration for EIA’s general thinking on its scenarios comes from the International Energy Information’s World Energy Outlook 2010 (WEO). In WEO, the IEA has three basic coal production scenarios that are highly dependent on government policy interventions to reduce greenhouse gas emissions. The Current Policies Scenario assumes no change in government policy, strong global economic growth and a near tripling of electricity demand in non-OECD countries. This lifts coal demand to over 7.5 billion metric tons by 2035, a 60% increase. In its New Policies Scenario, the IEA takes into account planned reforms of fossil-fuel subsidies and implementation of measures to meet climate and energy efficiency targets. Demand still rises, though modestly, by 18%. In the 450ppm Scenario, the IEA assumes that countries take decisive implementation of greenhouse gas reduction measures now and even more aggressive measures after 2020 with the objective of limiting to 2°C the long term rise in the global average temperature. In this scenario, world coal demand drops by 25% over the period.

IEA has not taken this analysis a step further to predict effects on prices, however, since the range of demand changes (+60% to -25%) are in more or less in line with the EIA price scenarios range (+72% to -39%) it is reasonable to use the latter as a ballpark estimate of what prices Chuitna coal could fetch in the Asian market on a competitive basis.

Gross revenues

Given these scenarios and an assumption of 12 million metric tons of production from Chuitna each year between 2015 and 2040, gross revenues can be projected over the life of the project. The revenue projections are summarized in Figure 2-3. Depending on which price scenario is chosen, annual revenues received from the sale of Chuitna coal in the Asian market could range between $1 and $1.2 billion in 2015, and $684 million to nearly $1.9 billion in 2040.

Present value

In accordance with standard NED procedures, these revenue streams can be discounted over the life of the project at a standard discount rate to arrive at a net present value figure for gross revenues. The choice of discount rate for Corps projects is critical, since most projects involve large up front construction costs and benefit streams that extend far into the future. So a small increase in the discount rate can have large implications for economic feasibility since it tends to dramatically reduce benefits for projects with long time horizons.

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There are two discount rates to consider: one that reflects the opportunity costs of capital investment, and one that reflects an individual's time preference for consumption now over consumption in the future.

With respect to investment, and for projects authorized primarily for private commercial gain, economists recommend that the rate should reflect the cost of displacing private investment, specifically the rate of return on capital in private markets.

Figure 2-3:

For projects authorized primarily for public uses, Corps discount rate formulas are tiered to the average yield of long-term government securities. Given that the Chuitna Coal Project, at least for the foreseeable future, is a project that will generate few if any public benefits, the appropriate discount rate is the former.

One method for calculating a discount rate that approximates the next best use of capital, known as the opportunity cost of capital (OCC), is the pre-tax return on investment. The pre-tax return on investment is the rate of return on private-sector investments, adjusted for inflation. Most federal benefit-cost analyses use a discount rate based on this approach as established by the Office of Management and Budget (OMB). Specifically, in Circular A-94, OMB sets a base discount rate that is the average rate of return to private capital consistent with national income and product accounts. The OMB believes that this rate is appropriate for evaluating public

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investments because it accounts for the displacement of private investment. The rate is currently set at 7%. This is the rate that will be used in calculations of the present value of Chuitna Coal Project costs.

To discount the benefit, or revenue stream, federal guidance is fairly consistent in using a rate that reflects the consumption rate of interest over the life of the project. In general, this rate will be lower than the opportunity cost of capital. As noted by EPA, 3 percent is commonly used for the consumption rate of interest. Using a discount rate of 3 percent Table 2-1 shows present value figures for gross revenues generated by the sale of Chuitna coal in the Asian import market under the four price scenarios described by Figure 2-3 using average prices for the 2015-2040 period.

Table 2-1: Present Value of Gross Revenues from Chuitna Coal Sales at a 3% Consumption Discount Rate

<table>
<thead>
<tr>
<th>Price Scenario</th>
<th>Average Price (2015-2040) ($/Mt)</th>
<th>Present Value ($2010 billions)</th>
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<tr>
<td>High cost coal</td>
<td>$125.02</td>
<td>$26.12</td>
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<tr>
<td>High oil price</td>
<td>$94.69</td>
<td>$19.79</td>
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<td>Reference case</td>
<td>$91.29</td>
<td>$19.08</td>
</tr>
<tr>
<td>Low cost coal</td>
<td>$74.46</td>
<td>$15.56</td>
</tr>
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2.1.1 Net revenues

From these gross revenue figures, the costs of production and transportation need to be deducted to estimate the potential magnitude of NED benefits associated with the sale of Chuitna coal on the Asian market. In Chapter 3, we arrive at a baseline financial cost estimate range of $52.26 to $88.05 per metric ton taking into account all capital and operating costs associated with the mine, the conveyor, Ladd Landing, and shipping costs to Asian ports. For now, we assume that these costs will remain relatively constant over the project life.

Table 2-2, below, deducts these costs from gross revenue figures reported in Table 2-1. By doing so, the resulting net present value figures – which range from -$2.84 to $15.20 billion – provide a first cut at the magnitude of NED benefits associated with development and operation of the Chuitna Coal Project with just direct, financial costs taken into account. It should be noted that the project would probably not be feasible from the standpoint of investor returns if future coal price trends fall much below the reference case scenario.

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94 See OMB Circular A-94 at: [http://www.whitehouse.gov/omb/circulars_a094#8](http://www.whitehouse.gov/omb/circulars_a094#8).

Table 2-2: Net Revenues from Chuitna Coal Sales at a 3% Consumption Discount Rate and Production Costs of $52.26 and $88.05 per Metric Ton

<table>
<thead>
<tr>
<th>Price Scenario</th>
<th>Net Revenue @ $52.26 ($/ Mt)</th>
<th>Net Present Value ($2010 billions)</th>
<th>Net Revenue @ $88.05 ($/ Mt)</th>
<th>Net Present Value ($2010 billions)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>$72.76</td>
<td>$15.20</td>
<td>$36.97</td>
<td>$7.73</td>
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<tr>
<td>High oil price</td>
<td>$42.43</td>
<td>$8.87</td>
<td>$6.64</td>
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<td>Reference case</td>
<td>$39.03</td>
<td>$8.16</td>
<td>$3.21</td>
<td>$0.67</td>
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<tr>
<td>Low cost coal</td>
<td>$22.20</td>
<td>$4.64</td>
<td>-$13.59</td>
<td>-$2.84</td>
</tr>
</tbody>
</table>

2.2 Regional Economic Development Impacts

Although not included in the actual accounting of a project’s net present value and benefit cost ratio, a discussion of jobs, income, and revenues to state and local government are often included in order to provide information about the regional economic development (RED) benefits of a proposed project. They are not included because these items are simply a different way to describe the costs of doing business – i.e. fees paid to the state, labor costs – so to include them in the benefit cost analysis would be to double count. Instead, these impacts are described in parallel, to help decision makers understand the beneficial effects of spending patterns by project developers. In this case, the RED benefits would result from PacRim’s planned expenditures of $500 - $600 million or so for project development plus annual operations and maintenance expenditures over a 25-year period.

2.2.1 Jobs and income

PacRim has provided estimates of 300-350 for long-term jobs associated with project operation, and 300-500 for project development.\(^{96}\) Weighted averages (assuming a 3 year construction period) suggest a range of 300 - 366 employees on an annual basis over a 28-year period. We can use these estimates of direct job creation in combination with published average labor cost data as well as multiplier data to predict indirect and induced jobs and income generated in the regional economy. Indirect jobs and income are created in the regional economy as local businesses that do business with the Chuitna mine and export facilities in turn spend their money to purchase supplies and services they need. Induced jobs and income are created as a result of the spending on local goods and services by households who directly benefit from the salaries they earn associated with the Chuitna Coal Project. Standard multipliers are used to calculate indirect and induced effects.

In 2006, the McDowell Group published multiplier data for Alaska’s coal industry based on estimates from regional economic impact models. The multipliers were 1.9 for jobs and 1.5 for personal income.\(^ {97}\) In other words, for every job directly created at Chuitna and every dollar paid for salaries, these multipliers suggest another 1.9 jobs and $1.50 in income are created as that money circulates through the local economy and benefits local households and businesses.

On an annual basis, the Alaska Miner’s Association publishes estimates for direct and total jobs created by the mining industry as a whole. The jobs multiplier used in the 2008 to 2011 publications is 1.57. Another estimate appears in a recent analysis of the proposed Wishbone Hill coal mine by the Institute of Social and Economic Research (ISER) at the University of Alaska. That analysis estimated the multiplier to be roughly 1.56. Given that the latter two estimates are derived from recent data, it is reasonable to adopt either. Using 1.57 then, construction and operation of the mine over the next 28 years could be expected generate total 471 – 575 total jobs in the regional economy each year.

As for income, there are several relevant estimates, drawn from the same studies. The McDowell (2006) study used a figure of $6,000,000 in direct income for the 92 jobs directly involved with coal mining operations, or $65,217 in 2004 dollars. This represents $75,291 in 2010 dollars. The ISER study reports average annual wages of $71,613 for both mine and port workers, $72,795 in 2010 dollars. An average of the two estimates is $74,043. Multiplying this by the range of direct employment yields a direct income estimate of $22,212,900 - $27,099,738 per year. The McDowell study assumes an income multiplier of 1.5 while ISER uses 1.16. The Alaska Miners Association annual reports used a multiplier range of 1.05 to 1.21 for the mining industry as a whole. The mean value is 1.13. The ISER estimate is the closest to this mean and perhaps the most precise, so using this yields a total direct, indirect, and induced income range of $25,766,964 - $31,435,696 per year.

2.2.2 Royalties, rents, and fees to state and local government

Both state and local governments in Alaska collect taxes on mineral production. State taxes include an income tax on net income to corporations, a mining license tax on all net income from product sales from all lands, a production royalty on net income from product sales from state lands, and miscellaneous taxes and license fees and reclamation bonding fees. State claim-related rents or leasehold assessment fees are collected in particular circumstances. In addition, boroughs levy property taxes, sales or excise taxes, and in a few cases, severance taxes on production.

Accurate estimates for public revenues generated by the Chuitna Coal Project cannot be calculated without more detailed economic and project configuration information. For example, until more precise information is made available about project costs, depreciation, and other exemptions that may apply, net income (and therefore) royalty and license fee predictions are difficult to make. However, as before, we can rely on published information for ballpark figures.

There are four relevant sources from which to draw. The first is Alaska’s Division of Geological and Geophysical Surveys, which publishes regular information circulars on Alaska’s mining industry. Its 2010 update provides information on the production value of coal produced in the state in 2007, 2008, and 2009. Production value is an important determinant of royalties and license fees. According to the report, production value has risen from $32.83 to $36.95 per

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ton over the past three years, or $36.12 to $40.65 per metric ton. This suggests that a value of $41 per metric ton is a reasonable short-term estimate.

The second source is the AMA series, which reports the total production value of all minerals produced in the state each year, and corresponding payments to state and local governments for property taxes, rents, royalties, fees, licenses, and other relevant obligations. AMA reports indicate an average of $4,902 per million dollars mineral production value paid to local governments and $33,384 to the state. A 12 million metric tons per year production rate from Chuitna at a production value of $41 per metric ton would yield $2,411,784 in annual local government payments and $16,424,928 to the state. Over the 25-year mine life, this would amount to $60.29 million in local government payments, and $410.62 million to the state. Revenues to Kenai Borough would also be generated through right of way easements and leases for the Ladd Landing coal export facility. Kenai Borough indicates that these payments are $70,838 per year with a lease term of 30 years. Total revenues over this period from the lease and easements would be $2,125,140.

The third and fourth sources are from PacRim’s forecasts (Note 96). In those forecasts, PacRim estimates local government payments to amount to $100 million to the Kenai Peninsula Borough and $300 - $350 million to the state ($4 and $12 million per year, respectively).

Table 2-3 summarizes these various estimates on regional economic development impacts.

### Table 2-3: Potential Regional Economic Development Impacts

<table>
<thead>
<tr>
<th>Impact</th>
<th>Lower bound (Annual)</th>
<th>Upper bound (Annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct jobs</td>
<td>300</td>
<td>366</td>
</tr>
<tr>
<td>Total jobs</td>
<td>471</td>
<td>575</td>
</tr>
<tr>
<td>Direct income</td>
<td>$22,212,900</td>
<td>$27,099,738</td>
</tr>
<tr>
<td>Total income</td>
<td>$25,766,964</td>
<td>$31,435,696</td>
</tr>
<tr>
<td>Local government revenues</td>
<td>$2,482,622</td>
<td>$4,000,000</td>
</tr>
<tr>
<td>State government revenues</td>
<td>$12,000,000</td>
<td>$16,424,928</td>
</tr>
</tbody>
</table>

---

Section 3:  
National and Regional  
Economic Development Costs

There are two primary categories of NED costs associated with authorization of the Chuitna Coal Project: (a) market or financial costs associated with development, operation, decommissioning and reclamation of the project over time, and (b) non-market costs that reflect the environmental, economic, and social costs not included in market prices. As established in Section 1, to comply with various requirements of the National Environmental Policy Act, Clean Water Act, Water Resources Development Act, Marine Protection, Research, and Sanctuaries Act as well as implementing regulations for these and other applicable statutes all relevant market and non-market costs should be considered. In this Section, we provide preliminary estimates of the range of both market and non-market costs associated with the Chuitna Coal Project based on publically available information. As this information is supplemented with project-specific cost data from the project record, we expect these estimates to be refined.

3.1 Financial Costs

The three most important categories of financial costs associated with the Chuitna Coal Project include capital costs incurred during development of the mine, conveyor system, and Ladd Landing export facility, annual operations and maintenance costs associated with these project elements, and transportation costs of shipping Chuitna coal to Asian ports. Table 3-1 identifies the important capital cost elements for each project element. An accurate estimate of capital costs would be based on multiple quotes from vendors who would supply the necessary equipment and labor, energy costs incurred during project development and operation, food and transportation costs for workers, and any relevant markups needed to account for the uncertainties associated with developing a project of this magnitude in a harsh climatic setting. In lieu of element-by-element cost data, our preliminary cost calculations rely on comparable cost data and cost modeling from the literature.

3.1.1 Mine development and operation

To estimate preliminary mine development and operation costs, we rely on an updated version of O’Hara (1980) and comparable mine cost data recently published by Shafiee et al. (2009). In 1980, O’Hara developed a set of exponential equations to estimate capital, stripping, equipment, maintenance, labor, and supply costs of new mines. Despite some limitations, these equations nonetheless are considered “still one of the best approaches in cost estimation literature.”

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for Chuitna in the absence of more accurate data from the project record. O’Hara’s original capital cost equation for new mines is given by:

\[ \text{Capital cost (\text{million})} = 400,000 \times (\text{tons mined and milled daily})^{.6} \]

### Table 3-1: Chuitna Coal Project Capital Cost Components

<table>
<thead>
<tr>
<th>Project component</th>
<th>Associated structures</th>
<th>Sub-structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chuitna coal mine</td>
<td>Surface coal mine</td>
<td>Stilling shed</td>
</tr>
<tr>
<td></td>
<td>Shop, office, and warehouse facility</td>
<td>Coal crusher</td>
</tr>
<tr>
<td></td>
<td>Fuel storage facility and fueling station</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical substation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ready line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30,000 ton covered surge bin and enclosed coal crusher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truck dump</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roads and power distribution</td>
<td></td>
</tr>
<tr>
<td>Conveyor and Other Infrastructure</td>
<td>Mine access road</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coal transport conveyor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personnel housing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air strip facility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power transmission facility</td>
<td></td>
</tr>
<tr>
<td>Ladd Landing Development</td>
<td>Logistical center</td>
<td>Warehouse and office building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open bulk storage and laydown area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulk fuel transfer and storage tanks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vehicle wash facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Septic tank and drain field</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water well, tank, and distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage and sediment control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Security fence and gates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Snow storage area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulkhead structure</td>
</tr>
<tr>
<td>Coal export terminal</td>
<td></td>
<td>Coal stockyard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment ponds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment wash facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10,000 foot trestle facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dredged channels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Offshore vessel berth</td>
</tr>
</tbody>
</table>

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Applying this equation to an expected 32,887 per day mean production rate at Chuitna and updating the result to 2010 dollars suggests an initial capital outlay of $543,259,069 to develop the mine. Annualized over 25 years with an opportunity cost of capital (OCC) of 7% (see discount rate discussion in Section 2) and then dividing the result by the expected annual production of 12 million metric tons yields a unit cost estimate of $3.88 per ton.

Corroboration for this ballpark cost figure comes from Shafiee et al. (2009) who present mine cost estimates for dozens of recent mines in Australia with a wide range of annual production rates and expected mine life. Annualizing their capital cost figures over expected mine life at an OCC rate of 7% and updating figures to 2010 U.S. dollars yields unit cost figures ranging from $1.79 to $9.67 per metric ton. The average across all recent (1998 and later) mines was $4.25 per ton, quite close to the O’Hara estimate for Chuitna. Given the relative proximity of these values and given a recent rough capital cost estimate from PacRim of $500 million we adopt the O’Hara estimate ($3.88) as the low end of our range and the Shafiee et al. (2009) midpoint ($4.25) as the high for the expected unit capital cost for developing the Chuitna mine.

In their paper, Shafiee et al. (2009) develop a new model of annual operations and maintenance costs to supplement O’Hara. They relate annual operations and maintenance costs per ton to deposit average thickness in meters (DAT), stripping ratio in tons overburden per tons coal (SR), capital cost in millions (CC), and daily production rate in thousand ton units (PR) in the following manner:

\[
\text{Estimated operating cost ($/Mt)} = 8.74 - .042 * \text{(DAT)} + 1.66(\text{SR}) - .00046(\text{CC}) - .041(\text{PR})
\]

According to the 1990 EIS, deposit thickness ranges from 1.6 to 6.1 meters with a stripping ratio (volume to weight) of 3.9 cubic meters of overburden for each metric ton of recoverable coal.\(^{104}\) To convert this ratio into a weight-to-weight measure, we assume an overburden weight range of 1.6 to 3 tons per cubic meter in accordance with standard weights for overburden composed of both rock and soil.\(^{105}\) These translate into a weight-to-weight stripping ratio of 6.24 to 11.7. We note that the range of ratios reported in Shafiee et al. (2009) are considerably higher (10.2 – 40.6) but feel these are unrealistic given the rather shallow nature of the Chuitna deposits. Using an average deposit thickness of 4 meters, a capital cost of $543 million and a daily production rate as before of 32,887 tons per day yields an operating cost range of $17.56 to $26.74 per ton.

Combined with capital costs, these figures suggest a mine-mouth price of Chuitna coal in the $21.44 to $30.99 range. This compares with a range of $20.13 to $22.83 (updated to $2010 dollars) estimated by the National Energy Technology Laboratory (NETL) in their 2006 feasibility study for the Beluga Coal Gasification plant using different methodologies than those presented here.\(^{106}\) The fact that these ranges overlap suggests that the either can be used as a

\(^{104}\) FEIS at 2-5.
\(^{105}\) See: http://www.ehow.com/facts_7551539_standard-crushed-rock-per-meter.html
reasonable first approximation of mine development and operation costs associated with the Chuitna Coal Project.

3.1.2 Conveyor costs

The second major project component is the 12 mile long conveyor system needed to transport coal from mine mouth to the Ladd Landing export facility. There are few publicly available sources of information to price out capital and operating costs for modern conveyor systems. Nor has PacRim made public the specifications for which system it intends to use. Nonetheless, we have developed rough estimates based on three sources of information. The first is the 2006 NETL study referenced above. In that study, NETL developed a unit cost estimate for transportation of Chuitna Coal to Ladd Landing via conveyor of $3 per metric ton, $3.25 in 2010 dollars, inclusive of both capital and operating costs.

The second is an older estimate of $.11 per ton-mile derived from a 1983 model published by Edgar (1983). This corresponds to a marginal cost of $3.49 per ton in 2010 dollars, quite close to the NETL estimate. The third is a recent cost to port estimate published by Devere Mining Technologies Limited for their breakthrough CARIAT (Continuous Articulated Rail In a Tube) system, purportedly the state of the art in coal conveyance systems. Devere reports $1.50 per ton for cost to port transport, $1.68 in 2010 dollars. It is unknown whether this type of system is applicable to Chuitna, but given that this cost estimate is significantly lower than either NETL (2006) or Edgar (1983) and could represent the limits of new technology it is reasonable to adopt it as a lower bound. Our conveyor cost range, then, is set at $1.68 to $3.49 per ton inclusive of all capital and operating costs pending the release of more precise Chuitna-specific cost data from PacRim.

3.1.3 Ladd Landing export facility costs

The third major cost category for the Chuitna Coal Project is costs associated with initial capital outlays during construction and annual operations and maintenance costs for the Ladd Landing export facility. Three sources of information provide a sense of the magnitude. The first is a detailed economic feasibility study completed by the Corps for the Delong Mountain Terminal Project (DMTP) along the northwest arctic coast near Kivalina Alaska. The Delong Mountain Terminal Project involved construction of port facilities with several project components similar to what will be needed at Ladd including an offshore trestle, ore concentrate loading capabilities, on-shore management facilities, fuel storage tanks, and dredged channels. Talberth et al. (2007) estimated capital costs for the trestle and on-shore facilities to be roughly $271 million (2010 dollars) and annual operating costs to be $8.4 million. Transferring these cost estimates to Ladd Landing suggests a unit cost of $2.64 per ton for Chuitna coal.

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The second estimate comes from NETL ($2006). The NETL study estimated combined capital and operating costs to be $3.25 per ton for loading Chuitna coal onto coal barges at Ladd Landing (2010 dollars). Costs associated with the Seward coal export facility were the basis of this cost estimate. The third estimate is costs reported for a coal export facility on the Russian Barents Sea coast. The details of the facility are not available; however, the capital cost range was reported to be $300 to $500 million for a facility capable of processing 18 million metric tons per year—just above the capacity planned for Ladd. Updating these figures to 2010 dollars and converting them into unit costs implies a range of $2.14 to 3.57 per ton. These two estimates form the lower and upper bound of our range since the other estimates fall in between.

3.1.4 Shipping costs

The cost of shipping Chuitna coal to Asian ports is, perhaps, the most uncertain cost component. Over the past decade, there has been tremendous variation in dry bulk cargo shipping costs across all types of carriers. The Australian floods and the global recession have added to that volatility. Until markets stabilize and the backlog of coal shipments from Australia is eased, price volatility will continue. Prior to the recession, Mjunction—a respected authority on dry bulk cargo rates—reported unit prices of $44 to $72 per ton for major coal routes from Australia to Asia across three sizes of coal carriers. HGCA, Inc. reported a similar range for dry bulk shipments from the U.S. to Asia. Currently, markets are depressed. Chinamining.org reports a current average of $27 per ton across all major coal routes. Given these pre and post recession estimates, we adopt a range of $27 to $50 per ton as a placeholder pending more precise unit cost estimates for shipments from Alaska.

3.1.5 Total unit cost range

Table 3-2 summarizes the foregoing analysis by reporting unit cost ranges for each of the four major cost elements. Taken together, capital and operating costs associated with development of the mine, conveyor, and Ladd Landing export facility and transportation costs for shipping Chuitna coal to Asia will likely fall in the $52 to $88 per metric ton range if the comparable cost estimates discussed in this section are indicative of costs associated with the Chuitna Coal Project.

Table 3-2: Preliminary Unit Cost Estimates

<table>
<thead>
<tr>
<th>Project component</th>
<th>Lower bound ($/Metric ton)</th>
<th>Higher bound ($/Metric ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal mine capital costs</td>
<td>$3.88</td>
<td>$4.25</td>
</tr>
<tr>
<td>Coal mine operations and maintenance costs</td>
<td>17.56</td>
<td>26.74</td>
</tr>
<tr>
<td>Conveyor costs</td>
<td>1.68</td>
<td>3.49</td>
</tr>
<tr>
<td>Export facility costs</td>
<td>2.14</td>
<td>3.57</td>
</tr>
<tr>
<td>Shipping costs</td>
<td>27.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Total:</td>
<td><strong>$52.26</strong></td>
<td><strong>$88.05</strong></td>
</tr>
</tbody>
</table>

111 See: http://www.mjunction.in/market_news/logistics_1/test_1.php
112 See: http://www.openi.co.uk/h070821.htm#r3
3.2: Non-market Costs

As previously noted, net public benefits analysis incorporates both market and non-market costs. With respect to the Chuitna Coal Project, important non-market costs include the externalities associated with pollution of air and water and the costs of lost ecosystem services associated with degradation of marine, riverine, and terrestrial habitats within the project area.

3.2.1 Carbon emissions damage

The reduction of greenhouse gas pollution is one of the most important environmental challenges humanity has ever faced given the catastrophic environmental, economic, and social costs of climate change now unfolding throughout the world. Economists predict that costs associated with climate change could represent up to 20% of gross world product by 2100. These costs are not reflected in the prices paid for oil, coal, or natural gas. As such, the production of these fossil fuel energy sources generates climate change related externalities to society that should be quantified and internalized if fossil fuel markets are to be efficient. The point of extraction is the logical place to assign such costs, since once fossil fuels are extracted and made ready for market, their combustion is assured.

Corps regulatory guidance specifically calls for quantification of externalities associated with projects authorized or financed by the agency. In Section 1.1.5 we identified various statutes and regulations that set forth this duty across a wide range of externalized cost sources including air and water pollution, habitat loss, degradation of scenery, loss of subsistence use and reduction in recreation and tourism.

Addressing the externalized costs of greenhouse gas emissions (GHGs) is, then, a necessary component of a comprehensive net public benefits analysis. The following analysis estimates externalities associated with GHG emissions (in carbon equivalent units) throughout the life-cycle of the Chuitna Coal Project from project development and operation to end use combustion of coal.

Scope of analysis

A thorough lifecycle emissions inventory would quantify the scope one, two, and three emissions produced from developing, operating, and maintaining the coal mine and associated support facilities. In addition, the inventory would include emissions from transporting extracted coal from Ladd Landing to end markets. Finally, the inventory would include emissions from combustion of the sold coal.

It is relatively straightforward to identify the components of a thorough lifecycle emissions inventory for the Chuitna Coal Project. However, a dearth of data makes it difficult to

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114 “Scope 1” emissions are directly emitted from the entity undertaking the emissions inventory. “Scope 2” emissions are once removed, and “Scope 3” emissions are twice removed, from the entity undertaking the emissions inventory.
quantify produced emissions. For example, no decision has been made on the design of the shop, office and warehouse facilities, so an assessment based on square footage or end use of that structure cannot be conducted. In another example, a literature review found no GHG emissions data for building and operating an electrical substation, surge bin, airstrip facility, and other project components. Assumptions could be made on emissions produced through those activities, but they would be so superficial as to be irrelevant.

Instead, a more robust inventory would focus solely on project activities that produce significant amounts of GHGs and have substantial findings from empirical research to support their emissions estimates. A literature review found three project components that meet those criteria:

- Extraction activities that produce methane (CH$_4$);
- Transportation that produces methane, carbon dioxide, and nitrous oxide (CH$_4$, CO$_2$, and N$_2$O); and
- Combustion that produces CH$_4$, CO$_2$, and N$_2$O.

Extraction that produces $CH_4$

Coal mining activities not including transportation and combustion accounted for one percent of total U.S. GHG emissions in 2008.$^{115}$ The only reported emitted gas was CH$_4$. Coal mining accounted for 12 percent of total U.S. CH$_4$ emissions in 2008, making it the fourth largest CH$_4$ source that year.

At least one report inventories individual mine contributions toward total CH$_4$ emissions from coal mining in the United States. Kirchgessner et al. (2000) developed two new spectroscopy techniques to estimate CH$_4$ emissions from thirty U.S. coalmines and published findings in 2000.$^{116}$ Emissions were estimated for underground mines, surface mines, and abandoned underground mines. The authors specifically note that emissions estimates for coal handling operations (i.e., components of the Chuitna support facilities and day-to-day operations) are "unavailable and impractical to collect."

The findings from Kirchgessner et al. (2000) that are most relevant to the Chuitna project are the surface coalmine emissions estimates (Table 3-3). Using their new spectroscopy techniques, the authors estimated cursory CH$_4$ emissions from thirty coalmines throughout the continental United States. They found that auger sites in Appalachia and lignite sites in Oklahoma, Texas, and the Dakotas emitted little or no CH$_4$. Those sites were excluded from further analysis. Rather, all measured CH$_4$ emissions were produced at non-lignite-and-auger sites in the Powder River region of Wyoming and Montana and the Northern Appalachian region of Pennsylvania. Based on those findings and the findings of other articles referenced in the

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report, the authors determined that emissions data from test sites could be extrapolated to all non-lignite-and-auger sites.

Table 3-3: Methane Emissions from Coal Mining

<table>
<thead>
<tr>
<th>Mine Site</th>
<th>Coal Production (10^6 tons/yr)</th>
<th>Methane Emissions (tons/yr)</th>
<th>Exposed Area (ft^2)</th>
<th>Methane Emissions Factor (tons/ft^2-yr)</th>
<th>Mining Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.00</td>
<td>1,354</td>
<td>3,089,429</td>
<td>0.000438</td>
<td>Powder River</td>
</tr>
<tr>
<td>B</td>
<td>16.80</td>
<td>1,253</td>
<td>3,389,056</td>
<td>0.000370</td>
<td>Powder River</td>
</tr>
<tr>
<td>C</td>
<td>9.90</td>
<td>786</td>
<td>1,911,686</td>
<td>0.000411</td>
<td>Powder River</td>
</tr>
<tr>
<td>D</td>
<td>15.50</td>
<td>1,369</td>
<td>3,203,366</td>
<td>0.000427</td>
<td>Powder River</td>
</tr>
<tr>
<td>E</td>
<td>1.20</td>
<td>43</td>
<td>129,168</td>
<td>0.000333</td>
<td>Northern App.</td>
</tr>
<tr>
<td>F</td>
<td>0.24</td>
<td>5</td>
<td>21,500</td>
<td>0.000241</td>
<td>Northern App.</td>
</tr>
<tr>
<td>Average</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td><strong>0.000370</strong></td>
<td>---</td>
</tr>
</tbody>
</table>

Source: Kirchgessner et al. 2010.

Based solely on coal production, study site “A” most closely matches the initial phase of Chuitna project development. The 20,571-acre lease area is divided into local mining units (LMUs). LMU1 is a 220,000,000-ft^2 site, though the entire area will not be developed at once. LMU1 is expected to produce 12,000,000 metric tons of coal per year. Assuming that the site will be non-lignite-and-auger\(^{117}\) and assuming that only a portion of the area is developed, a direct transfer of the projected CH\(_4\) emissions from site A would yield 1,228 metric tons per year.

Methane is a far more potent greenhouse gas than carbon dioxide, and so to represent methane emissions in terms of carbon dioxide equivalent units (CO\(_2\)e) requires multiplication of these emissions by a global warming potential emissions factor. For methane, that factor is 25. Thus, extraction of 12,000,000 metric tons of Chuitna coal per year could be expected to produce 1,228 x 25 or 30,700 metric tons of CO\(_2\)e per year. Over the 25-year life span of LMU 1, this amounts to **767,500 CO\(_2\)e**.

\(^{117}\) Lignite coal is the lowest-quality recoverable coal. The coal seam developed through the Chuitna project will be sub bituminous (see the combustion section for more information).
Transportation that produces \( \text{CH}_4, \text{CO}_2, \text{and N}_2\text{O} \)

Extraction and transportation activities will require heavy machinery and vehicles powered by fossil fuel combustion. Emissions from heavy machinery and vehicles used during the extraction phase are difficult to quantify because of the data issues discussed previously. However, calculation tools for mobile combustion provide a suitable option for calculating \( \text{CH}_4, \text{CO}_2, \text{and N}_2\text{O} \) emissions from transportation, particularly shipping.

The Greenhouse Gas Protocol (GHG-Protocol) developed by the World Resources Institute (WRI) is a methodology that guides entities through their emissions inventory. WRI has developed tools to support the GHG-Protocol process. One tool, the Mobile Combustion GHG Emissions Calculation Tool Version 2.0, produces emissions forecasts based on user-inputted data.\(^{118}\) Emissions forecasts are calculated using emissions factors from the U.S. Environmental Protection Agency.

To calculate emissions from a transportation event, a user inputs:

- **Region** as U.S., U.K., or other. The region category allows the tool to identify appropriate country-specific emissions factors.

- **Mode of transport** as road, rail, water, or aircraft. The mode of transport category corrects for the different rates of emissions delivery to the atmosphere from different environmental mediums. For example, emissions discharged underwater will have less global warming effect than emissions released directly into the air.

- **Scope** as scope 1 or 3. The scope category assists the user in organizing the emissions inventory.

- **Type of activity data** as vehicle distance, passenger distance, weight distance, custom fuel, or custom vehicle. The type of activity category provides the user with options for calculating emissions based on the available data.

- **Vehicle type** as one of twenty+ vehicle models. The vehicle type category refines the emissions estimate. The options available to the user are contingent on the type of activity data selected.

- **Distance traveled** as numeric distance in desired units. The distance traveled category is a key variable for calculating emissions for the entire journey.

- **Gross weight** as numeric value of vehicle and cargo in desired units. The gross weight category further refines the emissions estimate.

- **Unit of distance** as metric ton mile, short ton mile, short ton kilometer, or metric ton kilometer. The unit of distance category further refines the emissions estimate.

- **Fuel used** as one of twelve types of fuel. The fuel used category further refines the emissions estimate.

• **Fuel amount** as numeric amount in desired units. The fuel amount category further refines the emissions estimate.

• **Unit fuel amount** as one of seven fuel units. The unit fuel amount category further refines the emissions estimate.

The following user-inputted data applies for the Chuitna project:

• **Region**: US.

• **Mode of transport**: Water.

• **Scope**: 3.

• **Type of activity data**: Weight distance.

• **Vehicle type**: Very large bulk carrier (80,000 metric tons deadweight).

  For this analysis, a “very large bulk carrier” is assumed to be a Panamax ship at the maximum size possible and still able to travel through the Panama Canal.

• **Distance traveled**: 3,612 miles.

  Distance is calculated as an average to various ports with the Asian region, in nautical miles.

• **Gross weight**: 80,000 metric tons.

  The maximum deadweight for a Panamax ship is 80,000 tonnes (Lloyd’s 2007).¹¹⁹ A literature review did not find gross weight.

• **Unit of distance**: Ton mile (metric).

• **Fuel used**: Residual fuel oil 3s, 5, and 6.

  Residual fuel oil No. 6 is the standard fuel oil for shipping activities (GS 2010).¹²⁰

The user inputted data above generates 25,512 metric tons CO₂, 51,342 kg CH₄, and 256,774 kg N₂O for a one-way trip. Total transportation emissions in CO₂e over the twenty-five year mine lifespan are calculated as follows:

\[
\begin{align*}
(51,342 \text{ kg CH}_4/1000 \text{ kg}) & = 51.342 \text{ mt CH}_4 \\
(256,774 \text{ kg N}_2\text{O}/1000 \text{ kg}) & = 256.774 \text{ mt N}_2\text{O} \\
(25,512 \text{ mt CO}_2 \times 1 \text{ CO}_2 \text{ GWP}) & = 25,512 \text{ mt CO}_2\text{e} \\
(51.342 \text{ mt CH}_4 \times 25 \text{ CH}_4 \text{ GWP}) & = 1,284 \text{ mt CO}_2\text{e}
\end{align*}
\]


(256.774 mt N\textsubscript{2}O x 298 N\textsubscript{2}O GWP) = 76,519 mt CO\textsubscript{2e} \\

(25,512 mt CO\textsubscript{2e} + 1,284 mt CO\textsubscript{2e} + 76,519 mt CO\textsubscript{2e}) = 103,315 mt CO\textsubscript{2e} emissions for a one-way trip \\

If a single trip transports 70,000 mt of cargo and the mine is expected to produce 300,000,000 mt of coal over a twenty-five year lifespan, the total number of trips will be: \\

(300,000,000 mt of coal / 70,000 mt of cargo) = 4,286 one-way trips \\

(103,315 tonnes CO\textsubscript{2e} emissions for one-way trip x 4,286 one-way trips) = 442,808,090 mt CO\textsubscript{2e} \\

\textit{Combustion that produces CH\textsubscript{4}, CO\textsubscript{2}, and N\textsubscript{2}O} \\

According to the EPA’s draft scoping report, the Chuitna project will develop an ultra low sulfur sub bituminous coal reserve. By far, the largest amount of emissions associated with the project will be generated by combusting the extracted coal. Emissions vary among coal types and range from 215 pounds of CO\textsubscript{2} per million Btu for the lowest quality lignite coal to 227 pounds of CO\textsubscript{2} per million Btu for the highest quality anthracite coal (EIA 2010).\textsuperscript{121} Sub bituminous coal emits 213 pounds of CO\textsubscript{2} per million Btu. \\

Similar to its mobile combustion calculation tool, the GHG-Protocol has a tool for stationary combustion. The GHG-Protocol Tool for Stationary Combustion Version 4.0 produces emissions forecasts for the GHGs produced from coal combustion.\textsuperscript{122} The tool uses emissions factors from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories because country-specific emissions factors are not relevant for estimating emissions from all types of combustion.

To calculate emissions from combustion, a user inputs:

- \textbf{Sector} as energy, manufacturing, construction, commercial, institutional, residential, agriculture, forestry, or fisheries. The sector category provides direction for calculating CH\textsubscript{4} and N\textsubscript{2}O emissions that are affected in part on the machinery that combusts the fuel.
- \textbf{Fuel type} as solid fossil, liquid fossil, gaseous fossil, or biomass. The fuel type category affects the release rate of gasses into the atmosphere.
- \textbf{Fuel} as one of 15 fuels including sub bituminous coal. The fuel category is probably the most important factor for estimating emissions.

\textsuperscript{121} U.S. Energy Information Administration (EIA). 2010. “Questions about environment and emissions…” Available at http://www.eia.doe.gov/ask/environment_faqs.asp. \\

• **Amount of fuel** as numeric amount in desired units. The amount of fuel category refines the emissions estimate.

• **Units** as one of nine fuel units. The units category contains mass (e.g., tonnes, pounds) and activity (e.g., kWh, mmBtu) and further refines the emissions estimate based on available data.

The following user-inputted data applies for the Chuitna project:

- **Sector**: Energy.
  - Sub bituminous coal is used primarily for steam-electric power generation in coal-fired powered plants.
- **Fuel type**: Solid fossil.
- **Fuel**: Sub bituminous coal.
- **Amount of fuel**: 300,000,000.
- **Units**: metric ton.

The user-inputted data above generates 544,887,000 mt CO$_2$, 5,670 mt CH$_4$, and 8,507 mt N$_2$O.

Total combustion emissions in CO$_2$e over the twenty-five year mine lifespan would be:

\[
(544,887,000 \text{ tonnes } \text{CO}_2 + (5,670 \text{ mt } \text{CH}_4 \times 25 \text{ CH}_4 \text{ GWP}) + (8,507 \text{ mt } \text{N}_2\text{O} \times 298 \text{ N}_2\text{O} \text{ GWP})) = 547,563,836 \text{ mt CO}_2\text{e}
\]

**Social costs**

Based on the foregoing analysis, GHG emissions associated with development of the Chuitna Coal Project (LMU 1) over its 25-year life would be 991,135,140 metric tons (Table 3-4) or 39,645,405 per year. Such emissions represent a significant externalized economic cost in a world already suffering from the catastrophic effects of global warming. Putting aside the issue of who bears responsibility for internalizing these costs (i.e. customers who use electricity from coal fired plants, utilities, importers, or producers) it is clear that to be complete, an analysis of net public benefits from developing new coal sources needs to account for these costs to reflect the true costs of such decisions on society.

In terms of assigning a monetary value to this global externality, we rely on a meta-analysis of marginal damage costs from GHG emissions completed by Tol (2007).\textsuperscript{123} After reviewing 211 estimates, he found a mean social cost of $23 per metric ton carbon (tC). Dr. Tol raised his mean to $25/tC to accommodate uncertainty in the estimates. Using a $25/tC social cost and a 3 percent discount rate yields a present value figure of $17.26 billion, which translates into $57.53 for each ton of Chuitna Coal delivered to the Asian market and combusted in coal-fired plants.

### Table 3-4: Life Cycle Carbon Emissions Damage from the Chuitna Coal Project

<table>
<thead>
<tr>
<th>GHG emissions source</th>
<th>Total emissions (Metric tons CO2e)</th>
<th>Social costs (PV – $ billions)</th>
<th>$/ Metric ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction activities</td>
<td>767,500</td>
<td>$.02</td>
<td>$.05</td>
</tr>
<tr>
<td>Transportation (shipping)</td>
<td>442,808,090</td>
<td>$7.71</td>
<td>$25.70</td>
</tr>
<tr>
<td>End use combustion</td>
<td>547,563,836</td>
<td>$9.53</td>
<td>$31.78</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td>991,135,140</td>
<td>$17.26</td>
<td>$57.53</td>
</tr>
</tbody>
</table>

**Mitigating carbon emissions damage through offsets**

Offsets could provide an option for mitigating the $17.26 billion cost to society from Chuitna project activities. An offset is simply a reduction in emissions made in order to compensate an emission made elsewhere. Offsets may occur anywhere in the world because one metric ton of CO2e emitted in one region affects global warming the same as one metric ton of CO2e emitted in another region.

The fungible nature of offsets reduces the social cost of emissions from Chuitna project activities when the avoided emissions have a social cost lower than the $25/tC global average. In addition, offsets for the entire 25-year mine lifespan can be purchased up-front; thus avoiding the interest that raises social cost.

In *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Curve*, McKinsey & Company demonstrates potential practices to reduce emissions below 1990 GHG levels by 2030 (Figure 3-1). The McKinsey & Company analysis shows that companies have many options in selecting low-cost offsets projects to mitigate their emissions. Many of these projects would provide a net benefit to the company (i.e., those to the left of reduced slash and burn) while many would reduce significant emissions for a low capital cost (i.e., low-cost options to the right of small hydro).

Companies could enter a physical transaction to reduce emissions through a GHG emissions market, direct investment in an on- or off-site domestic or international capital project, or another exchange.

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3.2.2 Air quality damages

Each phase of the lifecycle of Chuitna coal (i.e., extraction, transportation, processing, combustion) will generate aerial pollutants with significant public health and ecosystem impacts. Regardless of where these pollutants are emitted, a comprehensive net public benefits analysis would account for these impacts, which represent a significant external economic cost.

This section identifies aerial pollutants produced during each phase of the lifecycle, notes their impacts, and assigns a social value to the produced coal based on marginal cost data reported in the literature. Since most Chuitna coal is likely to be exported to Asian markets and not used in the domestic United States, this section includes a short case study on the air quality impacts of combusted coal in China on California to illustrate the links between the two regions. A conclusion is that social value must be considered regardless of where the coal will be used.

_Aerial pollutants are produced during each phase of the coal lifecycle_

Each phase of the lifecycle to produce and use four dominant coal types (i.e., anthracite, bituminous, lignite, sub-bituminous) generates aerial pollutants. The extraction phase relies on machinery powered by fossil fuel combustion to remove coal deposits through underground or
surface mining. The machines emit greenhouse gases and criteria pollutants including sulfur
dioxide, nitrogen oxide, and particulate matter (i.e., SO$_2$, NO$_X$, PM$_{2.5}$, PM$_{10}$); the physical act of
extracting coal releases underground methane (CH$_4$); and the process of removing overburden
lying on top of coal seams releases aerial sediment and particulate matter. The transportation
phase generates the same pollutants as coal travels from the point-of-extraction to the point-of-
processing over rail, truck, or barge. During processing, machines that wash coal emit more
greenhouse gases and criteria pollutants, as well as arsenic, cadmium, lead, and mercury. The
combustion phase, however, produces the largest amount of aerial pollutants by far.

*Aerial pollutants impact people and ecosystems*

Aerial pollutants from phases of the coal lifecycle impact public health and ecosystems.
Particulate matter causes asthma, lung cancer, chronic obstructive pulmonary disease, and
emphysema. Brook et al. (2002) demonstrate the immediate impact of fine particles and ozone
on narrowing brachial and other arteries, aerial pollutants are linked to cases of acute myocardial
infarctions (i.e., heart attacks), and neurological impacts, such as stroke and loss of intellectual
capacity from mercury emissions, rise in accordance with long-term exposure to certain aerial
pollutants.\(^\text{125}\) Regarding ecosystems, the lifecycle phases could impair surface water quality by
increasing sediment and heavy metal concentrations. In addition, nitrogen aerial deposition from
NO$_X$ causes eutrophication and acid rain from SO$_2$ degrades tree canopy and affects fish
populations. There are many other impacts as well.

*Impacts can be used to assign a social cost to produced coal*

Impacts from aerial pollutants generated during different phases of the coal lifecycle cost
people, governments, and the private sector money. During treatment, patients consume limited
medical resources, cannot work and contribute to the economy, and require sick days that affect
productivity for businesses and companies. In the long-term, victims who are unable to work
may not realize their full professional potential. Likewise, impacts on ecosystems cost money
when reduced forest cover increases water treatment costs, mercury contamination renders fish
in recreation areas inedible, and acid rain causes unsightly defoliation that lower property values.
There are too many potential social costs to list them all here.

Several studies have attempted to assign a social cost to aerial pollutants produced during
the coal lifecycle. Most have focused on coal-fired power plants because of the large percentage
2009 all estimate the criteria air pollutant damages associated with individual coal-fired power
plants.\(^\text{126}\) EPA 2005 forecasts the benefits of reducing SO$_2$ and NO$_X$ from coal-fired power plants

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\(^\text{125}\) Brook, R.D., J.R. Brook, B. Urch, R. Vincent, S. Rajagopalan, and F. Silverman. 2002. "Inhalation of fine
particulate air pollution and ozone causes acute arterial vasoconstriction in healthy adults." *Circulation* 2002;
pollution and the triggering of myocardial infarction." *Circulation* 2001; 103(23): 2810–2815; Lockwood, A.H., K.
March 20, 2011).

\(^\text{126}\) Levy, J.I., L.K. Baxter, and J. Schwartz. 2009. "Uncertainty and variability in health-related damages from coal-
through the Clean Air Interstate Rule. While findings are similar, all analyses vary somewhat because they use different input data. Regarding impacts of aerial pollutants, the most influential impacts are the model for pollutant fate-and-transport (i.e., the model assumptions regarding dispersal of smokestack emissions), value of a statistical human life (VSL), included pollutants, and geographic region for the analysis. The studies mentioned here use different models and VSL values, but all include SO₂, NOₓ, PM₂.₅, and PM₁₀ and focus exclusively on the continental United States.

The most current of the analyses is NRC 2009. For the NRC forecast, authors used a model based on U.S. county-level emissions from 406 plants compared to more precise models based on sub-county grids and less precise models based on U.S. states. The VSL is $6,000,000 (USD 2000), which is approximately a mean value for other studies listed in the NRC report. The authors apply the value to all ages and assume that lives are lost in the same year as significant exposure. The last two assumptions are significant; other studies vary VSL depending on the victim’s age and assume the victim will still be productive for some time after exposure. The authors find aggregate damages associated with criteria-pollutant forming emissions from coal-fired electricity generation in 2005 were approximately $62 billion ($USD 2007). Costs were calculated on a per kilowatt hour (kWh) basis (Table 3-5) but the authors note that site-specific variables cause costs to vary greatly across the country.

Table 3-5: Mean Value of Criteria Air Pollutant Damages per kWh Associated with Emissions from 406 Coal-fired Power Plants in 2005

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Cents/kwh</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>3.800</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.340</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>0.300</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>0.017</td>
</tr>
<tr>
<td>Total (equally weighted)</td>
<td>4.400</td>
</tr>
<tr>
<td>Total (weighted by net generation)</td>
<td>3.200</td>
</tr>
</tbody>
</table>

Source: NRC 2009

The kWh estimate provides an easy way to assess the value of air pollutant damages for coalmines. Local mining unit (LMU) 1 in the Chuitna coal project could produce 300,000,000 tonnes of coal over the course of a 25-year lifespan. To determine the social value of air quality damages

1. Convert 300,000,000 tonnes to short tons (300,000,000 x 1.10231131 = 330,693,393 short tons);

2. Multiply 330,693,393 short tons by 17,000,000 Btu per short ton¹²⁷ (5.622 x 10¹⁵ Btu);

---

3. Divide $5.622 \times 10^{15}$ Btu by 3413 Btu per kWh\textsuperscript{128} ($5.622 \times 10^{15} / 3413 = 1.647 \times 10^{12}$); and

4. Update per kWh figures to $2010$ dollars.

5. Multiply $1.647 \times 10^{12}$ by corresponding values and divide by 100 to find dollar amount.

6. Divide by 25 and take present value to reflect cost stream over this period.

7. Divide by 300,000,000 metric tons to derive unit costs.

The present value of impacts from LMU 1 could be $53,092,868,407 ($176.98/mt) or $38,613,000,271 ($128.71/mt) depending on whether the estimate is based on simple weighting or weighting according to net generation (Table 3-6).

**Table 3-6: Air Pollution Damages Associated with Emissions from Chuitna Coal**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>4.00</td>
<td>$2,633,236,400</td>
<td>$45,852,934,339</td>
<td>$152.84</td>
</tr>
<tr>
<td>NO\textsubscript{X}</td>
<td>0.36</td>
<td>$235,605,360</td>
<td>$4,102,630,924</td>
<td>$13.68</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>0.32</td>
<td>$207,887,200</td>
<td>$3,619,970,517</td>
<td>$12.07</td>
</tr>
<tr>
<td>PM\textsubscript{10}</td>
<td>0.02</td>
<td>$117,802,680</td>
<td>$2,051,315,465</td>
<td>$6.84</td>
</tr>
<tr>
<td>Total (equally weighted)</td>
<td>4.63</td>
<td>$3,049,010,400</td>
<td>$53,092,868,407</td>
<td>$176.98</td>
</tr>
<tr>
<td>Total (net generation weighted)</td>
<td>3.37</td>
<td>$2,217,462,400</td>
<td>$38,613,000,271</td>
<td>$128.71</td>
</tr>
</tbody>
</table>

Air quality damage can extend to the United States

Aerial pollutants can transcend natural and political jurisdictions. For example, dust storms in China pick up air particulates from coal-fired power plants and carry them across the Pacific Ocean to the United States. Recent empirical analysis demonstrates the prominence of such particulates. From December 2007 to May 2008, University of California, Berkeley researchers collected particulate pollution samples from Chabot Observatory and Mount Tamalpais near San Francisco Bay. The sites were chosen where city pollution would be limited. The researchers filtered out PM2.5 from each site and measured concentrations of the isotope $^{208}\text{Pb}$. Spikes in the prevalence of the isotope corresponded to time periods of intense Asian dust storms, leading the researchers to conclude that emissions in eastern Asia were contributing to Bay area air pollution. The median portion of Asian lead in the PM\textsubscript{2.5} was 29 percent over a six-month time period.

The Berkeley study demonstrates a causal connection between east Asian coal combustion and aerial pollutants in the United States that cause significant public health and

\textsuperscript{128} Btu per kWh value is from Oak Ridge National Laboratory (ORNL). 2011. “List of Conversion Factors used by the Bioenergy Feedstock Development Programs.” Available at http://bioenergy.ornl.gov/papers/misc/energy_conv.html.
ecosystem impacts. The value of such pollutants can be assessed. The proposed Chuitna coal project will export coal to Asia and perhaps within the United States. In so doing, it will generate billions of dollars in costs for affected people in both Asia and the United States.

3.2.3 Ecosystem service damages

The proposed Chuitna Coal Project includes (1) a surface coal mine and associated support facilities; (2) a mine access road; (3) a coal transport conveyor; (4) personnel housing; (5) an air strip facility; (6) a logistics center, and (7) a coal export terminal at Ladd Landing. Construction and operation of these seven project components may adversely affect the long term productivity of a wide range of terrestrial and aquatic ecosystems and the economic benefits they provide on a sustainable basis.

Ecosystem service values of lands and waters in the Chuitna Coal Project area

Significant aquatic and terrestrial ecosystems include freshwater and coastal wetlands, riparian zones, lakes, ponds, bogs, muskeg, fen, spruce-hardwood forest, bottomland spruce-poplar forest, high brush, streams, rivers, shorelines, and near shore marine environments. In recent years, economists have coined the term “ecosystem services” to describe the various economic benefits intact lands and waters provide for human communities. The terrestrial and aquatic ecosystems affected by the Chuitna Coal Project provide all of these services. Ecosystem services are generally classified into four major categories.

- **Provisioning services** are the goods or products obtained from ecosystems such as food, freshwater, timber, and fiber. These services are tangible and many—but not all—are often tradable and priced in the marketplace. Terrestrial and aquatic ecosystems in the Chuitna Coal Project area provide fish, game, wood, berries, and medicinal plants gathered by native and subsistence users.

- **Regulating services** are the benefits obtained from an ecosystem’s control of natural processes such as carbon sequestration, erosion control, water flows, and pollination. Maintaining regular surface and groundwater flows of clean water is one of the major regulating services offered by terrestrial and aquatic ecosystems in the Chuitna Coal Project area in its natural state.

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132 FEIS at 4-83; Fall, James, Daniel J. Foster, and Ronald T. Stanek. 1983. The Use of Moose and Other Wild Resources in the Tyonek and Upper Yentna Areas: A Background Report. Anchorage: Alaska Department of Fish and Game, Subsistence Division.
• **Cultural services** are the nonmaterial benefits obtained from an ecosystem such as recreation, scenic and aesthetic enjoyment, and spiritual renewal. Fishing and hunting are two important recreational activities within the Chuitna Coal Project Area. These are enjoyed by both tourists and residents alike. The inland and offshore areas affected also provide scenic and aesthetic values important not only to direct users of the area, but all Alaskans.

• **Supporting services** are natural processes—such as nutrient cycling, primary production, and water cycling—that maintain the other ecosystem services. For example, marsh and muskeg wetlands within the Chuitna Coal Project area can contribute to flow of nutrients within freshwater and marine environments.

These benefits create jobs, income, and value in the Cook Inlet and Alaskan economy through many different channels. Sport fishing generates jobs and income in the local economy through angler expenditures on vessels, fuel, tackle, and supplies. As these expenditures circulate through the regional economy, they create even more jobs and income indirectly by way of the multiplier effect. According to Helvoigt et al. (2010), direct expenditures for sport fishing in Cook Inlet in 2007 totaled more than $730 million.

Combining both direct and indirect effects, the Alaska Department of Fish and Game estimates that sport fishing was responsible for an estimated $828 million in economic output, $279 million in regional income, and about 8,000 jobs in Cook Inlet in 2007. Commercial fishing also generates significant economic benefits to the Cook Inlet economy. Helvoigt et al. (2010) estimated the wholesale value of salmon harvested from Cook Inlet to be over $61 million and total economic impact to be over $100 million each year. Over 1,000 jobs were supported by this activity.

The value of personal and subsistence uses of fish, game, and wild plants is another indicator of ecosystem service values associated with the Chuitna Coal Project area. In many cases, the cost to replace the ecosystem services provided by intact landscapes and aquatic ecosystems would place a significant economic burden on local residents, if they could be replaced at all. According to Helvoigt et al. (2010), roughly one-half of Tyonek and Beluga residents rely on wild foods and during the 2005–06 study year, the community of Tyonek harvested more than 43,000 pounds of wild resources, averaging 664 pounds per household and 217 pounds per person.” Salmon and moose represent the largest share. Using a replacement

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135 According to State of Alaska’s Division of Oil and Gas, Department of Natural Resources: “The entire coastline of the Cook Inlet basin holds an abundance of vistas, natural features, and man-made scenic resources of varying aesthetic value. Scenic resources may include wetlands, tideflats, beaches, vertical bluffs, rocky coasts, lakes, stream corridors, undulating hills, bays, and inlets. They may be enclosed in a wooded canopy or open with one or more unique natural features in view.” See:


136 FEIS at 4-13 to 4-14.


139 Helvoigt. 2010. Note 134.
cost” (i.e., what would it take to replace this harvest with commercial purchases in stores) value of $7.36/ lb in accordance with Alaska Department of Fish and Game methods suggests the annual value of Tyonek’s subsistence harvest to be roughly $320,000.140

Northern Economics (2006) evaluated the consumptive and non-consumptive value of moose in Alaska, considering benefits associated with sport and subsistence food supply, tourism, and aesthetic appreciation (i.e., passive use). Annual benefits totaled $47 million. The discounted present value of moose to Alaska’s economy over a 20-year period was estimated to be $476 million (in 2010 dollars).141

Intact wildlands and resources throughout the Chuitna Coal Project area generate significant scenic and aesthetic values. Economists refer to scenic and aesthetic values as “passive use” values, because people hold these values even if they never directly use the resource in question. They are measured by survey methods that measure people’s willingness to pay to protect these resources. For example, Colt (2001) concluded that passive use values for 13.2 million acres encompassed by Bristol Bay Wildlife Refuges were in the order of $2.5 billion a year, or $3.5 billion in 2010 dollars. This translates into a value of $268 dollars an acre each year.142 There is no reason why undeveloped landscapes surrounding Cook Inlet would not generate a similar magnitude of passive use benefits.

Helvoigt et al. (2010) found Alaska’s annual marginal non-use willingness to pay for a Upper Cook Inlet salmon to be $4.19 and the total annual non-use economic value of the entire Upper Cook Inlet salmon fishery to be approximately $294 million per year, aggregated across Alaska’s total population. Talberth et al. (2007) found Alaskan household’s mean willingness to pay to be $22.56 per year to maintain passive use values for marine ecosystems and Beluga habitat jeopardized by expansion of port facilities for the Red Dog mine along the Arctic coast.143 This translates into an annual value aggregated across all Alaskan households of $5,580,000 per year to maintain passive use values on the nearshore and offshore areas that would otherwise be disturbed by port construction, ship traffic, and ocean dumping of dredged material.

These scenic and aesthetic values, in turn, play an important role in the regional economy by providing the basis for nature-based tourism. Nature-based tourism is big business in Alaska, and Cook Inlet sightseeing and boating are a significant part of this industry (Colt 2001). Alaska’s visitor industry accounted for a total of 36,200 full and part-time jobs in 2008-09, over

140 The replacement cost method and per pound value estimate are described in “Subsistence In Alaska: 1994 Update Division of Subsistence, Alaska Department of Fish and Game.” The 2010 value of the $5 per pound figure used in that study is $7.36.

3-20
$1.1 billion in labor income, and $3.4 billion in total spending, including all direct, indirect and induced effects.\textsuperscript{144}

Some studies tie together multiple ecosystem services to estimate the economic value of particular ecosystems on a per acre basis. According to the Millennium Ecosystem Assessment (2005) the economic value of 63 million hectares of wetland around the world is between about $200 billion a year and $940 billion for a subset of important ecosystem services.\textsuperscript{145} This translates to between $1,435 and $6,745 per acre per year in 2010 dollars. A meta-analysis by the Economic Research Service found median market, non-market, and ecological function wetland values to be $48,208 in 2010 dollars across a number of studies.\textsuperscript{146} A study sponsored by NOAA for the Washington State Department of Ecology estimated the value of flood protection alone to be $10,869 to $69,287 per acre in 2010 dollars depending on local circumstances.\textsuperscript{147} The wide range of these values reflects the necessity of site-specific valuation studies.

Nonetheless, if the mean from this range ($35,361) reflects wetland values in the Chuitna Coal Project area, it implies ecosystem service values from wetlands and other waters (i.e., ponds) to be in the order of $64,710,630 each year for the 1,830 acres of wetlands and waters affected by the project’s footprint.\textsuperscript{148} Thus, ecosystem services provided by intact aquatic and terrestrial ecosystems within the Chuitna Coal Project area are a significant source of value to the Alaska and Cook Inlet economy on a sustainable basis.

On-site and offsite impacts of the project

As currently planned, the Chuitna Coal Project will likely cause irreparable damage to these ecosystem services. There are no studies of which CSE is aware that suggest reclamation of surface coal mining will restore ecosystem service benefits or values to their baseline condition. In particular, there have been no documented successful (i.e. pre-mining functions and values) reclamation examples of a wild salmon stream in cold, wet conditions similar to conditions that exist at the Chuitna Coal Project site. Indeed, what literature exists suggests that damage is permanent. For example, the Environmental Protection Agency (EPA) this spring announced that it will use its authority under the Clean Water Act to halt the proposed disposal of mining waste in streams at the Mingo-Logan Coal Company’s Spruce No. 1 coal mine in West Virginia.\textsuperscript{149} Similar to Chuitna, the proposed fill affects an area of high fishery and clean water values. EPA’s final decision to veto the permit focused on an exhaustive review of the science showing

\textsuperscript{149} U.S. Environmental Protection Agency. 2011. Final Determination of the U.S. Environmental Protection Agency Pursuant to § 404(c) of the Clean Water Act Concerning the Spruce No. 1 Mine, Logan County, West Virginia.
the irreparable harm that occurs when mining companies permanently bury and pollute natural headwater streams with mining waste.

The Chuitna Coal Project jeopardizes ecosystem service functions and values in several ways, most directly through habitat loss, fragmentation, and disruption of both surface and groundwater flows, and more indirectly through water pollution. Many impacts are predicted by the 1990 Final Environmental Impact Statement (FEIS), including:

- Sheetgale-grass fen, a key wetland ecosystem plant, would decline from 291 acres to 0 acres;
- Rearing habitat for coho and Chinook salmon in the Chuitna River drainage could be reduced by 40 to 80 percent depending on mining plans and the success of stream restoration;
- Chinook salmon escapement could decline by 30 percent per year in the later years of mine life;
- Spawning habitat for 23,571 Chinook rearing salmonids, 57,208 coho, and 14,615 Dolly Varden could be lost after 10 years of mining activity. After 30 years, 91,086 Chinook rearing salmonids, 179,348 coho, and 14,615 Dolly Varden could lose habitat;
- Stream flow could be reduced by 8.5 to 25 percent in Lone Creek;
- Stream channel length in Stream 2003 could be reduced by 46,570ft;
- Watershed area for Stream 2003 could be reduced by 5.75mi²; and
- Stream flow for Stream 2004 could be reduced by 21 percent.

The FEIS also notes that the Diamond Chuitna Coal Project would have reduced open water from 18 to 0 acres and spruce birch, a key wetland ecosystem type, from 984 to 549 acres. There are also likely to be significant impacts to areas that are downstream from the mine, including the impacts to marine ecosystems associated with development and operation of the coal export terminal at Ladd Landing.

Impacts to marine ecosystems are likely to be diverse, and long lasting. They include loss of intertidal wetlands, disturbance to the seafloor associated with construction of a 10,000 foot trestle, an increase of 150 to 250 vessel transits per year, planned and accidental discharges of sediment, coal, oil, and toxic substances, changes in local ice flow patterns, noise, and disruption of habitat use patterns by fish and marine mammals.

Impacts to terrestrial and aquatic ecosystems are likely to cause damage to important aesthetic values and long-range productivity of ecosystems within the project area. The potential magnitude of economic impacts can be estimated by combining reported ecosystem service values discussed above with the predicted changes in ecological conditions associated with

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150 In their intervention memo for the Trustees for Alaska petition, PacRim Coal, LP notes that the EPA issued final permits based on information contained in the FEIS. In so doing, they supported the notion that the project should proceed. In addition, PacRim notes that changes to mitigate the environmental impacts of the project have been made since the FEIS was received in 1990. Nonetheless, the FEIS remains the only document that details impacts from developing lands associated with the Chuitna Coal Project.

151 The flow reduction would likely occur in year 10 of mine life and end at the end of mine life.

152 HDR. 2006. Note 148; FEIS at 5-95-5-111.
project development and operation. Preliminary estimates can be made for loss of fisheries, loss of passive use values for terrestrial ecosystems, loss of passive use values for marine ecosystems, and loss of wetlands. Because such impacts will extend well beyond the operations phase of the mine, we have modeled the impacts out over a 50 year period, a standard time horizon for Corps civil works projects.

**Loss of passive use values for fisheries**

If the long term projected loss of salmonid habitat and fish production occurred today, it would represent a discounted loss of aesthetic (i.e., passive use) values of nearly $31 million over a 50-year period, or $0.10 per ton of production. Impacts to fisheries can be expected to extend well beyond the mine life, so a 50-year time horizon is used in accordance with standard Corps procedures. This value assumes a loss of $1,194,355 per year for 285,049 fish with passive use values of $4.19 per fish when none of the lost production would be restored by reclamation activities. One could argue that not all habitat loss would occur immediately; it would be spread out over the project life. On the other hand, the impacts of initial project development include a range of disturbance factors for fish, such as increased runoff and water pollution, so it is reasonable to front-load fisheries impacts towards the earlier phases of the project. Regardless, the magnitude of this figure illustrates the potential significance of lost aesthetic values associated with the project’s impacts on salmon.

**Loss of passive use values for terrestrial ecosystems**

According to the scoping report, the development of LMU 1 would impact roughly 5,050 acres of terrestrial and aquatic ecosystems in the upland portion of the project area. Another 360 acres would be impacted by the proposed airstrip and housing facilities. Additional acreage would be affected by the 12-mile access road. With respect to habitat loss, a general rule of thumb is 5 acres per mile,¹⁵³ which translates into 60 acres for the Chuitna project.

If the Colt (2001) passive use value calculation of $268 per acre is applied here to the 5,470 acres of direct impact it suggests an annual loss of $1,465,960. As with fishery impacts, it is reasonable to “front load” these impacts to the earlier project phases to account for indirect effects such as habitat fragmentation. Modeled over a 50-year period, this translates into a present value cost of $37,718,804 associated with loss and degradation of terrestrial ecosystems in the project area. This represents an additional unit cost of $0.13 per ton of production.

**Loss of passive use values for marine ecosystems**

Given the relatively high ecological values of marine ecosystems affected by the Chuitna Coal Project, passive use values are also likely to be high. Recently, this fact was underscored by the final designation of critical habitat for the Cook Inlet beluga whale. In its April 8th, 2011 notice, NOAA designated 3,016 square miles of marine and estuarine environments considered by scientists to be essential to the whale’s survival as critical habitat including cetacean feeding

areas at the mouths of important salmon streams. All of the marine ecosystems affected by the Chuitna Coal Project fall into this critical habitat designation, and so passive use values associated with beluga whales are a reasonable proxy for values associated with these ecosystems as a whole. As part of the preparatory analysis for the designation, NOAA recognized the significance of passive use values for beluga whales:

- Passive use value to society of critical habitat designation reflects the increased well-being obtained from the knowledge that Cook Inlet beluga whales persist within their natural habitat in Cook Inlet. Society would not derive the same level of well-being (i.e. would not have an equivalent WTP) for a remnant population of Cook Inlet beluga whales being kept in an artificial environment, such as an aquarium tank at the Port of Anchorage” (italics in original).

Passive use values for at risk species and the magnitude of losses associated with projects that put these species at risk can be empirically measured, primarily through contingent valuation surveys. A recent meta-analysis of a set of 29 U.S. studies found annual household willingness to pay values for actions to protect threatened and endangered species to range from $11 to $350 in 2006 dollars. Of particular relevance for an assessment of the economic value of critical habitat for the Cook Inlet beluga whale are non-market valuation studies that focus on estimating the public’s WTP for protecting threatened and endangered marine mammals in the United States. The NOAA analysis cited a WTP range of $16.18 to $142 per household per year for a range of U.S. studies addressing a wide variety of species.

One non-U.S. study addressed beluga whales in particular. Olar et al. (2007) used CV methods to estimate the WTP to improve the St. Lawrence beluga whale population, a distinct population group of the species in Canada, from its current threatened status to not a risk at all (i.e., to fully recovered). Using an Internet panel-based sample, consisting of 2,006 Canadians (52% response rate), they estimated the mean household WTP to be $122 per year (2006 Canadian dollars).

As discussed previously, there are few Alaska studies available to estimate passive use values for preservation of beluga whales or other aspects of the marine ecosystems affected by the Chuitna Coal Project. However, the Talberth (2007) study cited previously is directly on point, since it addressed WTP to preclude a project of a similar magnitude and range of impacts as Chuitna, such as increased mine production, port facilities, a trestle, increased ship traffic, and beluga habitat. The mean household WTP value reported in that study – $22.56 – for a marine protected area designation that would preclude development of the Delong Mountain Terminal

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Project can therefore be used as a preliminary estimate of passive use values at risk. This value is within the range of other values reported in the literature, but conservative. True values are likely to be considerably higher, since the beluga stocks considered in that study were far from Alaska’s population center, and not listed as threatened. On the other hand, since the Chuitna Coal Project affects only a portion of Cook Inlet beluga habitat, WTP values to preclude its adverse impacts (i.e. through a similar MPA designation) may not be as high as the literature suggests.

Extending this $22.56 WTP value to all Alaska households (236,597 from the most recent census estimates) implies annual passive use damages of $5,337,628, a present value cost of $137,335,917 over 50 years, and a unit cost of $0.46 per ton.

*Loss of wetlands*

Long term productivity losses associated with reduction of food, fiber, water supply, and other ecosystem services provided by wetlands in the project's footprint could amount to a present value cost of $1,664,989,238 over a 50-year period assuming the mean marginal (i.e., per acre) wetland values previously discussed are valid for the Chuitna Project area. This represents $5.55 per ton of production. However, this figure does not account for actual mitigation costs associated with wetland loss in Alaska, which can be considered an additional regulatory compliance cost related but not necessarily overlapping with lost ecosystem service values.

As noted above, the Chuitna Coal Project footprint is expected to affect 1,830 acres of wetlands and aquatic ecosystems. State and federal regulations could require project developers to avoid, minimize, or mitigate the impacts to these aquatic resources. The State of Alaska identifies two types of wetlands for which mitigation is required. Freshwater wetlands are environments characterized by rooted vegetation that is partially submerged either continuously or periodically by surface freshwater with less than 0.5 parts per thousand salt content and not exceeding three meters in depth” and saltwater wetlands are “coastal areas along sheltered shorelines characterized by halophilic hydrophytes and macro algae extending from extreme low tide to an area above extreme high tide that is influenced by sea spray or tidally induced water table changes.”

At least two state-level permitting programs affect waters that meet these definitions. Applicable to both freshwater and saltwater wetlands, the Alaska Department of Natural Resources (ADNR) awards permits to projects that will affect “rivers, lakes, and streams or parts of them that are important for the spawning, rearing, or migration of anadromous fish.” Also applicable to both types, the federal Clean Water Act (CWA) §401 provides the Alaska Department of Environmental Conservation (ADEC) authority to certify federal activities that discharge into waters of the United States and coastal zones. All Corps public notifications for CWA §404 permits also request §401 certification.

The CWA §404 permits are the federal regulations that affect wetlands in Alaska. As part of the CWA §404 permitting process, through §401 or other requirements, applicants are often required to compensate for unavoidable impacts to jurisdictional waters by providing mitigation. In some circumstances, such as for discharge into coastal zones, ADNR reserves authority to
determine whether or not Corps mitigation requirements satisfy state requirements. If not, ADNR may impose additional mitigation requirements.

Mitigation can occur through three actions: 1) permittee-responsible compensatory mitigation; 2) credit purchases from a mitigation bank; or 3) in-lieu fee mitigation. Mitigation actions result in additional costs for project developers. The developer pays for mitigation. In practice, many factors (e.g., aesthetic, wildlife habitat, and recreation benefit) affect the choice of mitigation practice. From the economic perspective, however, a rational developer would choose the least-cost option. In some cases, permittee-responsible compensatory mitigation is the least-cost option, but in most cases, mitigation banks or in-lieu fees are cheaper.

According to the Environmental Law Institute (ELI), Alaska had one mitigation bank (i.e., Natzuhinni Wetland Mitigation Bank) and four wetland and stream in-lieu fee programs (i.e., Alaska Great Land Trust Program, Alaska Kachemak Heritage Land Trust, Alaska Southeast Alaska Land Trust, and Alaska Conservation Fund) as of 2008. More recently, the Corps authorized use of the Su-Knik Mitigation Bank in the Fish Creek Watershed, Little Susitna Watershed and the Lower Susitna Watershed. An internet review was unable to find costs for mitigation bank credits in Alaska. However, Ecosystem Marketplace (2011) notes that wetland credit prices range from $6,000 to $300,000 depending on the location.

Another consideration is the ratio that converts impacted wetlands to required credits. Wetland credits are calculated as one acre of impacted wetland to between one and three acres of restored wetland. If a credit payment does not create a new wetland, the ratio can range from one to ten. Taking the mid-point of credit prices ($153,000) but applying no ratio suggests mitigation bank costs for the Chuitna Coal Project to be $279,990,000, which translates into $0.93 per ton of production. However, since mitigation bank credit prices are not made public, a more refined estimate may be to use in lieu-fee rates as a proxy, as suggested by Ecosystem Marketplace.

The Alaska Great Land Trust sets in-lieu fee rates annually. The rates are based on the cost to offset wetland impacts in Anchorage so could be higher than the cost for in-lieu fees for the Chuitna Coal Project. Developers are assessed a fee based on the Relative Ecological Value (REV) of their project. The Corp’s methodology for calculating REV is set forth in a technical

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161 See: http://www.su-knikmitigationbank.com/


 manual that is now being revised. For projects deemed to impact wetlands with high REV, the cost is greater. For projects deemed to impact wetlands with lower REV, the cost is less. As of the February 1, 2011, the following rates were charged:

- REV 1 Debit: $163,891 per acre
- REV 2 Debit: $163,891 per acre
- REV 3 Debit: $18,795 per acre

In comparison, Ecosystem Marketplace lists the following rates:

- $24,000 - $46,000 per acre of non-riparian wetland in North Carolina
- $36,000 - $63,000 per acre of riparian wetland in North Carolina
- $156,000 per acre of coastal wetland in North Carolina
- $55,000 - $65,000 per acre of nontidal wetland in Southeast Virginia
- $125,000 - $150,000 per acre of nontidal wetland in Northern Virginia
- $400,000 - $653,000 per acre of tidal wetland in Virginia
- $84,500 per acre of wetland in Oregon

The Corps has yet to disclose how many acres of wetlands impacted by the Chuitna Coal Project fall into the various REV categories. However, draft 2010 guidance suggests that there may be a significant amount of this acreage in the REV 1 and 2 categories. For example, wetlands that support salmonids generally fall into REV 1 or 2, as do intertidal wetlands important to shorebirds and beluga whales. Thus, it is reasonable to assume that affected wetlands fall into all three categories.

Assuming an equal distribution and that no credit ratio applies, an in-lieu fee mitigation cost would be $(163,891 \times 610 \text{ (REV1)} + 163,891 \times 610 \text{ (REV2)} + 18,795 \times 610 \text{ (REV3)}) = 211,411,970$ or $0.70$ per ton of production. If the payment were spread out over a 50 year period commensurate with other ecosystem service damage estimates, it would amount to roughly $4,228,220 in annual costs, however, in-lieu fees are typically paid up front so this figure is for comparison purposes only.

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166 See: Table 1: Polygons, and Relative Ecological Values (REVs), Grouped by Landform, 2010 draft update to the debit-credit methodology.

167 The Corps does include a category of lower ecological value – REV4 – but it appears that few if any acres in the Chuitna Coal Project area would be classified as such.
Table 3.7 summarizes the potential magnitude of damages to ecosystem services in terms of annual costs, net present value, and unit costs per ton of production.

### Table 3-7: Ecosystem Service Damages

<table>
<thead>
<tr>
<th>Ecosystem Service Damage</th>
<th>Annual costs ($2010)</th>
<th>Present value ($ millions)</th>
<th>$/ Metric ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive use damage - fisheries</td>
<td>$1,194,355</td>
<td>$30.73</td>
<td>$0.10</td>
</tr>
<tr>
<td>Passive use damage - terrestrial ecosystems</td>
<td>$1,465,960</td>
<td>$37.72</td>
<td>$0.13</td>
</tr>
<tr>
<td>Passive use damage - marine ecosystems</td>
<td>$5,337,628</td>
<td>$137.34</td>
<td>$0.46</td>
</tr>
<tr>
<td>Use and non-use damage - wetlands</td>
<td>$64,710,630</td>
<td>$1,665.00</td>
<td>$5.55</td>
</tr>
<tr>
<td>Mitigation cost – wetlands</td>
<td>$4,228,220</td>
<td>$211.41</td>
<td>$0.70</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$76,936,793</strong></td>
<td><strong>$2,082.20</strong></td>
<td><strong>$6.94</strong></td>
</tr>
</tbody>
</table>

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168 Mitigation costs are typically paid up front. The annual cost figure is indicated here for comparative purposes only.
The Chuitna Coal Project will involve numerous federal and state authorizations to proceed. As discussed in depth in Section 1, these authorizations require that federal and state agencies including the Army Corps of Engineers (Corps) Environmental Protection Agency, National Marine Fisheries Service, and Alaska Department of Natural Resources consider the potential economic impacts of the proposal from the standpoint of net public benefits and not restrict their analysis to the financial benefits to mine owners, the state, and local government. The Corps regulatory framework operationalizes the net public benefit analysis requirements in its National Economic Development (NED) and Regional Economic Development (RED) procedures. These procedures represent the best analytical methods and science available to the agency with respect to economic analysis.

In Sections 2 and 3, we provide preliminary estimates of the likely magnitude of several important categories of NED and RED benefits and costs. These preliminary estimates are based on publicly available information and not more detailed project specific information that PacRim will provide to the Corps and other federal and state agencies during the permitting process. Thus, the preliminary estimates should be considered ballpark figures that will be refined as the permitting process unfolds.

4.1: Net Present Value and Benefit-cost Ratio

The net public benefits framework relies on two key metrics: net present value and the benefit cost ratio. Tables 4-1 and 4-2 consolidate figures from Sections 2 and 3 into estimates of net present value and the benefit-cost ratio under each of the long term price assumptions and for the low and high delivered coal cost estimates of $52.26 and $88.05 per metric ton. Even under the most optimistic price scenarios, the social costs of the Chuitna Coal Project are likely to exceed social benefits by a wide margin as reflected by negative net present value figures and benefit-cost ratios below one in these tables. Taking these costs into consideration suggests a net present value range of -$57.23 to -$75.27 billion over the life of the project and a benefit-cost ratio range of .3134 to .1713, meaning that costs exceed benefits by a factor of 3 to 6.

A slightly different metric evaluates the social costs relative to market prices. The comparison is provided in Table 4-3. This analysis suggests that the social costs of Chuitna coal are likely to range between 193 and 604% of the market value depending on the long-term prices in Asia or locally in Alaska, a range that is consistent with values reported in the literature. For example, in a 2002 review, Cherry and Shogren (2002) found the social costs of coal to range from 300 to over 650% of the market price.\footnote{Cherry, Todd L. and Jason F. Shogren. 2002. The Social Cost of Coal: A Tale of Market Failure and Market Solution.} Given this, the only way the Chuitna Coal Project could proceed in a manner consistent with net public benefits is a tax on production that recoups these externalized costs or major reconfiguration of the project to internalize or mitigate these damages.
Table 4-1: Cumulative Net Present Value (billions) and Benefit-Cost Ratio under the Four Price Scenarios and a Delivered Cost of $52.26/ Metric ton

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>High coal cost NPV</th>
<th>High coal cost BCR</th>
<th>High oil price NPV</th>
<th>High oil price BCR</th>
<th>Reference case NPV</th>
<th>Reference case BCR</th>
<th>Low coal cost NPV</th>
<th>Low coal cost BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial costs alone</td>
<td>$15.2</td>
<td>2.3900</td>
<td>$8.87</td>
<td>1.8100</td>
<td>$8.16</td>
<td>1.7500</td>
<td>$4.64</td>
<td>1.4200</td>
</tr>
<tr>
<td>-Carbon emissions damage</td>
<td>-2.06</td>
<td>0.9269</td>
<td>-8.39</td>
<td>0.7023</td>
<td>-9.10</td>
<td>0.6771</td>
<td>-12.62</td>
<td>0.5522</td>
</tr>
<tr>
<td>-Air quality damages</td>
<td>-55.15</td>
<td>0.3214</td>
<td>-61.48</td>
<td>0.2435</td>
<td>-62.19</td>
<td>0.2348</td>
<td>-65.71</td>
<td>0.1915</td>
</tr>
<tr>
<td>-Fisheries damage</td>
<td>-55.18</td>
<td>0.3213</td>
<td>-61.51</td>
<td>0.2434</td>
<td>-62.22</td>
<td>0.2347</td>
<td>-65.74</td>
<td>0.1914</td>
</tr>
<tr>
<td>-Terrestrial ecosystem damage</td>
<td>-55.22</td>
<td>0.3211</td>
<td>-61.55</td>
<td>0.2433</td>
<td>-62.26</td>
<td>0.2346</td>
<td>-65.78</td>
<td>0.1913</td>
</tr>
<tr>
<td>-Marine ecosystem damage</td>
<td>-55.36</td>
<td>0.3206</td>
<td>-61.69</td>
<td>0.2429</td>
<td>-62.40</td>
<td>0.2342</td>
<td>-65.92</td>
<td>0.1910</td>
</tr>
<tr>
<td>-Use and non-use value for wetlands</td>
<td>-57.02</td>
<td>0.3142</td>
<td>-63.35</td>
<td>0.2380</td>
<td>-64.06</td>
<td>0.2295</td>
<td>-67.58</td>
<td>0.1872</td>
</tr>
<tr>
<td>-Mitigation cost wetlands</td>
<td>-57.23</td>
<td>0.3134</td>
<td>-63.56</td>
<td>0.2374</td>
<td>-64.27</td>
<td>0.2289</td>
<td>-67.79</td>
<td>0.1867</td>
</tr>
</tbody>
</table>

Table 4-2: Cumulative Net Present Value (billions) and Benefit-Cost Ratio under the Four Price Scenarios and a Delivered Cost of $88.05/ Metric ton

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>High coal cost NPV</th>
<th>High coal cost BCR</th>
<th>High oil price NPV</th>
<th>High oil price BCR</th>
<th>Reference case NPV</th>
<th>Reference case BCR</th>
<th>Low coal cost NPV</th>
<th>Low coal cost BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial costs alone</td>
<td>$7.73</td>
<td>1.4200</td>
<td>$1.39</td>
<td>1.08</td>
<td>$0.67</td>
<td>1.04</td>
<td>-52.84</td>
<td>0.85</td>
</tr>
<tr>
<td>-Carbon emissions damage</td>
<td>-9.53</td>
<td>0.7325</td>
<td>-15.87</td>
<td>0.5550</td>
<td>-16.59</td>
<td>0.5351</td>
<td>-20.10</td>
<td>0.4363</td>
</tr>
<tr>
<td>-Air quality damages</td>
<td>-62.62</td>
<td>0.2943</td>
<td>-68.96</td>
<td>0.2230</td>
<td>-69.68</td>
<td>0.2150</td>
<td>-73.19</td>
<td>0.1753</td>
</tr>
<tr>
<td>-Fisheries damage</td>
<td>-62.65</td>
<td>0.2942</td>
<td>-68.99</td>
<td>0.2229</td>
<td>-69.71</td>
<td>0.2149</td>
<td>-73.22</td>
<td>0.1753</td>
</tr>
<tr>
<td>-Terrestrial ecosystem damage</td>
<td>-62.69</td>
<td>0.2941</td>
<td>-69.03</td>
<td>0.2228</td>
<td>-69.75</td>
<td>0.2148</td>
<td>-73.26</td>
<td>0.1752</td>
</tr>
<tr>
<td>-Marine ecosystem damage</td>
<td>-62.83</td>
<td>0.2936</td>
<td>-69.17</td>
<td>0.2225</td>
<td>-69.89</td>
<td>0.2145</td>
<td>-73.40</td>
<td>0.1749</td>
</tr>
<tr>
<td>-Use and non-use value for wetlands</td>
<td>-64.49</td>
<td>0.2882</td>
<td>-70.83</td>
<td>0.2184</td>
<td>-71.55</td>
<td>0.2105</td>
<td>-75.06</td>
<td>0.1717</td>
</tr>
<tr>
<td>-Mitigation cost wetlands</td>
<td>-64.70</td>
<td>0.2876</td>
<td>-71.04</td>
<td>0.2179</td>
<td>-71.76</td>
<td>0.2101</td>
<td>-75.27</td>
<td>0.1713</td>
</tr>
</tbody>
</table>

Table 4-3: Ratio of Social Costs to Market Price

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>High coal cost</th>
<th>High oil price</th>
<th>Reference case</th>
<th>Low coal cost</th>
<th>AK production value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market price ($/ Metric ton)</td>
<td>$125.02</td>
<td>$94.69</td>
<td>$91.29</td>
<td>$74.46</td>
<td>$40.00</td>
</tr>
<tr>
<td>Social costs ($/ Metric ton)</td>
<td>$241.44</td>
<td>$241.44</td>
<td>$241.44</td>
<td>$241.44</td>
<td>$241.44</td>
</tr>
<tr>
<td>Ratio (Social costs/ market price)</td>
<td>1.93</td>
<td>2.55</td>
<td>2.64</td>
<td>3.24</td>
<td>6.04</td>
</tr>
</tbody>
</table>

4.2: Future Refinements

This preliminary analysis provides an estimate of the potential net public benefits associated with the Chuitna Coal Project based on publicly available sources of information as of April 2011. It provides a snapshot of important categories of costs and benefits that must be taken into account from the broad perspective of net public benefits, and not financial costs and benefits alone.

As the permitting process unfolds, more detailed information on Asian market conditions, project development and annual operations costs, transportation costs, tax liabilities, and project configuration will make more refined estimates possible. This new information will help reduce the range of variation in the estimates. For example, as countries continue to pursue low carbon development strategies in China and throughout Asia, it may be more likely that coal prices will
continue to decline from their recent historic highs making the high cost coal price scenario unrealistic and thus excluded from future analysis. More precise project development and transportation cost data provided by PacRim would enable more accurate estimates of delivered coal costs, as well as jobs, income, and tax benefits to the regional economy.

However, given the wide margin of social costs over national economic development benefits estimated in this preliminary analysis and the fact that our estimates corroborate figures reported in the literature, it is unlikely that future refinements would affect project economics in any significant way. This underscores the dilemma of developing new coal sources in an era of global warming and increasing damages from air and water pollution. While market demand may support new coal mine development from the perspective of project investors, such projects are not justified from a net public benefits perspective because they generate social costs far in excess of private financial benefits.
Economic Benefits of Instream Flow Protection
For Middle Creek (Stream 2003), Alaska

Prepared for Cook Inletkeeper

By

Dr. John Talberth
Center for Sustainable Economy

1.0 Key points

- In adjudicating Chuitna Citizens Coalition’s applications to reserve water in Middle Creek (Stream 2003), the Alaska Department of Natural Resources (ADNR) must consider a comprehensive menu of benefits to all Alaskans.
- The framework of ecosystem services is the standard decision-making framework for federal and state public agencies tasked with assigning values to intact natural resources.
- Ecosystem service benefits of the Middle Creek watershed are likely to be in the range of $55.4 million to $134.2 million each year, or a present value of $1.4 billion to $3.5 billion over 50 years.
- Instream flow benefits are a sub-component of ecosystem services provided by Middle Creek. The literature on instream flow benefits per acre-foot suggests an annual value of instream flow on Middle Creek to be in the order of $7.1 million to $17.0 million each year, or a present value of $183.4 million to $436.6 million over 50 years.
- In its cursory evaluation of benefits, ADNR considered just one small value – the market value of coho – and excluded all other ecosystem services. Moreover, ADNR underestimated this one benefit by a factor of ten or more by erroneously using exvessel prices as a measure of value and using an unrealistically low figure for survival rates.
- Using market prices rather than exvessel prices, the value of adult coho in Middle Creek is likely to range between $129,292 and $150,808 per year, a present value of $3.3 million to $3.9 million over 50 years.
- The value of sportfishing associated with Middle Creek’s fishery was ignored by ADNR, but is likely to range between $403,210 and $470,310 per year, a present value of $10.4 million to $12.1 million over 50 years.
- ADNR must also consider the avoided costs associated with development of the Chuitna coal mine. Development of this mine would generate economic losses to the public of between $58.78 billion and $78.01 billion. Granting CCC’s application would avoid this loss.

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2.0 Background

In 2009, the Chuitna Citizens Coalition (CCC) filed applications to reserve water within the main, middle, and lower reaches of Middle Creek (also known as Stream 2003), near Beluga, Alaska, for the purpose of maintaining specified instream flow rates to protect fish and wildlife habitat, migration, and propagation.\(^2\) The Alaska Department of Natural Resources (ADNR) is adjudicating these applications. The applications were filed pursuant to Alaska’s Water Use Act, which, in pertinent part, requires ADNR to issue the instream flow reservation if (1) the rights of prior appropriators will not be affected by the reservation; (2) the applicant has demonstrated that a need exists for the reservation; (3) there is unappropriated water in the stream or body of water sufficient for the reservation; and (4) the proposed reservation is in the public interest.\(^3\)

As part of the public interest determination, ADNR prepared a brief report quantifying one specific economic benefit that would arise in association with a grant of the application – the ex-vessel present value of adult coho salmon that will inhabit the stream over the next 25 years.\(^4\) ADNR did not include in the administrative record any other information on additional economic benefits associated with the proposal. Nor did ADNR consider the costs avoided by granting the applications, namely, the wide range of public costs that will be incurred if the Chuitna coal mine is developed, such as the social costs of carbon emissions. Granting instream flow protections for Middle Creek will protect over a dozen miles of salmon bearing stream that would otherwise be destroyed by the proposed coal strip mine. This report provides a more comprehensive overview of the numerous economic benefits associated with Middle Creek in its natural state, as well as a discussion of avoided costs associated with preclusion of the Chuitna Coal Strip Mine.

3.0 The public interest standard of review

ADNR’s public interest determination must rest on an evaluation of eight distinct factors enumerated by Alaska’s Water Use Act: “(1) the benefit to the applicant resulting from the proposed appropriation; (2) the effect of the economic activity resulting from the proposed appropriation; (3) the effect on fish and game resources and on public recreational opportunities; (4) the effect on public health; (5) the effect of loss of alternate uses of water that might be made within a reasonable time if not precluded or hindered by the proposed appropriation; (6) harm to other persons resulting from the proposed appropriation; (7) the intent and ability of the applicant to complete the appropriation, and (8) the effect upon access to navigable or public water.”\(^5\)

From an economics standpoint, this is a fairly comprehensive list. It includes costs and benefits not only enjoyed or incurred by the applicant, but by all Alaskans. Everyone’s costs and benefits

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\(^2\) Alaska DNR’s Notice of Applications for Reservation of Water in Middle Creek can be reviewed online at: https://aws.state.ak.us/OnlinePublicNotices/Notices/View.aspx?id=175666.
\(^3\) Alaska Statutes (AS) 46.15.145(c); 11 Alaska Administrative Code (AAC) 93.146(a).
\(^5\) AS 46.15.080(b).
matter, and ADNR’s duty is to be as comprehensive as possible.\textsuperscript{6} In this matter, the costs and benefits relevant to the public interest standard can be distilled into two broad categories: ecosystem service benefits and opportunity costs associated with preclusion of the Chuitna mine.

\textbf{4.0 Duty to quantify ecosystem service benefits}

In 1997, Gretchen Daily is credited with having offered the first formal definition of ecosystem services: “\textit{[e]cosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life.”\textsuperscript{7} The most ubiquitous definition of ecosystem services used today is a more generalized one: “[e]cosystem services are the benefits people obtain from ecosystems.”\textsuperscript{8} The concept of ecosystem services thus encompasses all of the benefit categories enumerated in the public interest standard set forth in AS 46.15.080(b).

\textbf{4.1 Types of ecosystem services present in Middle Creek}

Ecosystem services fall into three broad categories:

1. Provisioning services, which refer to the food, fuel, fiber, and clean water that ecosystems provide.
2. Regulating services, which refer to specific ecosystem processes for which people are willing to pay. Examples include pollination, storm protection, climate regulation, and water regulation.
3. Cultural services, which refer to the benefits ecosystems confer that do not directly relate to our physical health or material wellbeing. Examples include recreation, aesthetic, spiritual, existence, and option “values.” Whereas the first two of these are experiential, the latter “non-use” values depend simply on the continued survival of the ecosystem and its attributes.\textsuperscript{9}

The natural ecosystems of the Middle Creek watershed at issue in the adjudication of CCC’s application include the creek, adjacent riparian buffers, wetlands, swamps, fen, scrub, meadow and forest habitats within its drainage.\textsuperscript{10} Middle Creek is a 2nd-order stream draining 9,126 acres, is approximately 16.4 feet wide, and enters the Chuitna River approximately 11.2 miles upstream from Cook Inlet. The mean annual discharge is 33.90 cubic feet per second (cfs) and

\textsuperscript{10} A grant of CCC’s application will alter the area affected by the Chuitna Coal Mine, and thus increase protection for all these ecosystem types throughout the Middle Creek watershed.
the stream is 18.6 miles long.\textsuperscript{11} Vegetation profiles of the proposed Chuitna coal mine area (which encompasses an eleven mile segment of Middle Creek) can be used as a basis for approximating the distribution of vegetation communities throughout the entire watershed.\textsuperscript{12} For purposes of ecosystem service valuation, it is most useful to convert vegetation inventories into the categories used in the National Land Cover Dataset (NLCD) maintained by the US Geological Survey.\textsuperscript{13} The NLCD is the standard used in many ecosystem service studies. The result of this exercise is reported in Table 1, below. Wetlands constitute, by far, the most prominent land cover type, followed by mixed (spruce-birch) forest, alder scrub, and fireweed meadows.

### Table 1
**Approximate Land Cover Acreage for Middle Creek (Stream 2003) Watershed**

<table>
<thead>
<tr>
<th>Land cover type</th>
<th>Acres</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed forest</td>
<td>3,292.76</td>
<td>36.08%</td>
</tr>
<tr>
<td>Coniferous forest</td>
<td>72.64</td>
<td>0.80%</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>59.71</td>
<td>0.65%</td>
</tr>
<tr>
<td>Shrub/scrub</td>
<td>954.29</td>
<td>10.46%</td>
</tr>
<tr>
<td>Riparian buffer</td>
<td>451.00</td>
<td>4.94%</td>
</tr>
<tr>
<td>River</td>
<td>37.00</td>
<td>0.41%</td>
</tr>
<tr>
<td>Meadows</td>
<td>833.89</td>
<td>9.14%</td>
</tr>
<tr>
<td>Wetlands</td>
<td>3,424.71</td>
<td>37.53%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,126</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Throughout the Chuitna watershed including Middle Creek, these land cover types provide a wide range of ecosystem goods and services valuable to residents of the Native village of Tyonek and those who visit from other parts of Alaska and beyond.\textsuperscript{14} In terms of provisioning services, the Chuitna watershed supports subsistence and personal-use harvesting of fish, game, and berries. Chinook and coho salmon are the most important fish species caught; however, rainbow trout, steelhead, and Dolly Varden are taken in lesser numbers. Moose, brown bear, and black bear hunts are significant to residents and are the primary game mammals harvested for food. Other important game species include both migratory and upland birds. Pelts from beaver, river


\textsuperscript{12} HDR Alaska, Inc. 2007. Baseline Report for Vegetation and Wetlands. Cheyenne, WY: Mine Engineers, Inc. Acres for river and riparian buffers were estimated based on Nemeth et al. 2010 and the assumption of a 100 foot riparian buffer on either side of the creek.

\textsuperscript{13} The National Land Cover Database for Alaska is available online at: [http://www.mrlc.gov/nlcd11_data.php](http://www.mrlc.gov/nlcd11_data.php).

\textsuperscript{14} The description of existing uses is based on Oasis Environmental Inc. 2006. Land Use Baseline Summary Report for the Chuitna Coal Project. Anchorage, AK: DRven Corporation.
otter, lynx, wolverine, and marten are sold in local markets. Most Tyonek residents use wild plants and berries, and these represent “the highest use level of any wild resource category.”

In terms of regulating services, Middle Creek’s remote fish stocks also help maintain the stability of fisheries throughout the region due to what is known as the “portfolio effect.” According to Schindler et al. (2010), “[o]ne of the most pervasive themes in ecology is that biological diversity stabilizes ecosystem processes and the services they provide to society, a concept that has become a common argument for biodiversity conservation. Species-rich communities are thought to produce more temporally stable ecosystem services because of the complementary or independent dynamics among species that perform similar ecosystem functions. Such variance dampening within communities is referred to as a portfolio effect and is analogous to the effects of asset diversity on the stability of financial portfolios.” Another provisioning service supported by Middle Creek’s salmon fishery is its role in depositing marine derived nutrients (MDN) into riverine systems. These MDN’s play a major role in shaping ecosystem functions and the growth and condition of aquatic, riparian and terrestrial flora and fauna.

In terms of cultural services, the Chuitna watershed supports an important sport fishery, primarily for Chinook and coho salmon. There are several local outfitting businesses and charters that “take advantage of the pristine environment and low fishing pressure” on the Chuitna River. Other important recreational uses include snow-machining, berry picking, camping, swimming, water skiing, and hiking. The pristine environment of the Middle Creek watershed also provides intrinsic, or non-use values held by all Alaskans. For example, by applying research findings from Pacific Northwest rivers to salmon escapement counts for rivers and streams in the Upper Cook Inlet area, ECONorthwest estimated that Alaska’s annual marginal non-use willingness to pay for a Upper Cook Inlet salmon to be $3.98 (2010 dollars) and the total annual non-use economic benefit of the entire Upper Cook Inlet salmon fishery to be approximately $280 million per year, aggregated across Alaska’s total population.

4.2 Ecosystem service valuation and agency decision-making

The duty to quantify ecosystem service effects in natural resource decision-making was recently reiterated and refined in a process led by the Council on Environmental Quality (CEQ) and

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18 Oasis Environmental, 2006, Note 11.
seven federal Departments and agencies. The end result was a set of Principles, Requirements, and Guidelines (PR&G) for all federal agencies whose decisions affect water resources. The PR&G recognizes that “[r]educed service flows over time amount to costs, and increased service flows over time amount to benefits.” A complete accounting identifies impacted services, their value, and trends over time. The PR&G also sets the standard for consideration of ecosystem services by state-level agencies that participate with these federal Departments and agencies in water resource related decision-making. This includes decisions related to the Chuitna coal mine, which involves several federal agencies, ADNR and other state agencies.

The importance of ecosystem service valuation has been recognized by the State of Alaska. For example, the Alaska Department of Environmental Conservation endorses ecosystem service valuation in assessing the value of damaged natural resources and the compensation needed to “to make the environment and public whole following a discharge of oil or hazardous materials.” In particular, “[c]ompensation can be monetary payments for injury to, destruction of, or loss of natural or cultural resources, and the value of the lost services provided by those resources.”

The Alaska Department of Fish and Game regularly evaluates the economic value associated with its management programs, and uses peer reviewed methods of ecosystem service valuation to quantify the economic benefits associated with hunting and wildlife viewing trips. For example, in its 2011 evaluation, the ADFG used the contingent valuation method to determine “the amount households would have been willing to pay for wildlife-related goods and services beyond what they actually paid. This method has been employed for decades and natural resource economists generally agree that contingent valuation can yield a reliable estimate of what the public is willing to pay for wildlife-related goods and services.”

5.0 Methods for ecosystem service valuation are readily available to ADNR

Over the past three decades economists have developed a wide range of methods for assigning monetary values to ecosystem services. All of these methods are available to ADNR for use in the public interest evaluation for Middle Creek. The choice of method depends upon the general type of ecosystem service (provisioning, regulating, cultural) whether the service provides direct or indirect benefits to those affected and whether or not economic value is associated with use of the ecosystem or associated with its non-use values.

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20 These include: Department of the Interior, Department of Agriculture, Department of Commerce, Environmental Protection Agency, Army Corps of Engineers, Federal Emergency Management Agency and Tennessee Valley Authority.
22 Id.
23 Lead and cooperating agencies are listed here: http://www.chuitnaseis.com/links.html.
25 Id.
The distinction between direct, indirect and non-use values is illustrated in Table 2 below, adapted from the US National Research Council. Direct use benefits of ecosystem services are those that involve some kind of physical interaction, such as the extraction of fish or freshwater for drinking from a river or most forms of recreation. Indirect use benefits are those that do not necessarily involve physical interaction but nonetheless represent a beneficial use; for example, the flood control benefits of wetlands that protect certain properties downstream even though the property owners who may benefit may not actually visit the wetlands providing this service.

### Table 2

**Major Classification of Ecosystem Service Values and Some Examples**

<table>
<thead>
<tr>
<th>Use values</th>
<th>Non-use values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct</strong></td>
<td><strong>Indirect</strong></td>
</tr>
<tr>
<td>Commercial and recreational fishing</td>
<td>Flood control</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>Water purification</td>
</tr>
<tr>
<td>Hunting</td>
<td>Storm protection</td>
</tr>
<tr>
<td>Fuelwood and timber</td>
<td>Wildlife and fish habitat</td>
</tr>
<tr>
<td>Recreation</td>
<td>Pollination of crops</td>
</tr>
<tr>
<td>Genetic material</td>
<td>Carbon sequestration</td>
</tr>
<tr>
<td></td>
<td>Existence value for imperiled species</td>
</tr>
<tr>
<td></td>
<td>Existence value for outstanding scenic areas</td>
</tr>
<tr>
<td></td>
<td>Cultural heritage values for spiritual sites</td>
</tr>
<tr>
<td></td>
<td>Cultural heritage values for national landmarks</td>
</tr>
<tr>
<td></td>
<td>Bequest values for aquifer protection</td>
</tr>
<tr>
<td></td>
<td>Bequest values for farmland protection</td>
</tr>
</tbody>
</table>

Non-use values (also referred to as passive use values) on the other hand, are intrinsic values people may hold for preservation of a resource even though they may not receive any direct or indirect benefits from it but they are willing to pay for such protection. Non-use values include those associated with protecting biodiversity or natural landmarks for their own sake (existence values), preserving indigenous cultures (cultural heritage values) or the desire to pass on resources for future generations (bequest values).

The concept of total economic value (TEV) is used to describe the sum of all of these values – use, non-use, direct and indirect. TEV provides the most comprehensive measure of ecosystem service benefits and thus represents the “gold standard” when conducting valuation studies. For example, the TEV framework is now widely used in to identify the costs and benefits associated with protected areas.

When original valuation studies are undertaken methods for quantifying these values are generally grouped into three major categories: revealed preference approaches, stated preference approaches, and cost-based approaches. When budgets do not allow for original valuation

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studies, researchers use what is known as benefits transfer method. Below is a brief description of these groupings and methods within them.

5.1 Revealed preference approaches

Revealed preference methods of measuring ecosystem service values are based upon actual behavior in organized markets. In other words, value is revealed through direct market purchases of ecosystem goods or services or purchases of other goods or services whose prices are influenced by environmental quality. Specific techniques include:

- **Market prices**: Valuations are directly obtained from what people actually pay for the ecosystem good or service in formal markets. Examples include the prices paid for fish, game, non-timber forest products, or recreational access.

- **Travel cost**: Valuations of site-based amenities are implied by the travel costs people incur to enjoy them. For example, average purchases of fuel, food, and airline tickets to visit a particular natural area can be used to derive the value of a recreational visit.

- **Hedonic pricing**: The value of a service is implied by what people will be willing to pay for the service through purchases in related markets, such as housing markets. A typical example of a situation amenable to use of hedonic pricing is the premium people are willing to pay for houses that are adjacent to parks and open space or which have spectacular scenic vistas. This price premium can be translated into a corresponding ecosystem service benefit per acre.

- **Factor income**: Ecosystem service values are derived from their impact on yields and income from marketed products. For example, agricultural yields have been shown to be greater in fields that retain more biodiversity. The increase in farmers’ income is thus a signal of the underlying value of biodiversity.

5.2 Stated preference approaches

Stated preference methods of measuring non-market values use surveys or interviews to ask people directly about their willingness to pay for some good or service or to rank alternative management scenarios and ecological attributes. The surveys typically involve a choice about a hypothetical or proposed situation. A distinct advantage of stated preference methods is that they allow researchers and policy makers to target preferences for specific components of environmental changes, such as existence value. A disadvantage is that survey results can be affected by strategic responses, or responses that are designed to influence the outcome of the research, rather than by honest responses. Researchers have also found that some people are not willing to trade money for a loss in environmental quality. Specific techniques include:

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• **Contingent valuation**: People are directly asked their willingness to pay or accept compensation for some change in an ecosystem service or environmental quality. For example, the survey would ask respondents to state their maximum willingness to pay each year into a fund to acquire and protect habitat for an endangered species.

• **Choice experiments**: Asking a series of questions about a respondent’s relative preferences for various management strategies and associated ecological conditions. For example, respondents choose between various levels of water quality with different management strategies and associated costs of achieving those levels. There will typically be three or four alternative strategies with similar attributes (per question) presented.

• **Conjoint analysis**: A variant of choice experiments where people are asked to rank (rather than choose one) ecological conditions created by various management strategies. For example, respondents would assign ranks to various scenarios for wetlands management that involve tradeoffs between flood control benefits and fishery yields.

### 5.3 Cost-based approaches

Cost-based methods use historical cost data or projections to quantify the costs society would incur if an ecosystem were lost or what it would take to replace an ecosystem service with a technological solution. There are three primary methods:

- **Avoided cost**: This method assigns values to ecosystem services based on costs that would be incurred in their absence. For example, forests, wetlands, and mangroves provide many flood control benefits. If they were lost, loss of life, property, and damage to infrastructure would increase.

- **Replacement cost**: Valuing ecosystem services by calculating the cost of replacing them with technological solutions. For example, replacing natural fisheries with a system of hatcheries or wild pollinators with industrial bee hives.

- **Restoration cost**: Restoration cost is a method used to calculate the cost of restoring an ecosystem to its natural state after it has experienced some environmental damage, such as an oil spill. Or it involves calculating the cost of restoring ecosystems on damaged landscapes—such as promoting the natural regeneration of woodlands on areas that have been overgrazed by livestock. The cost of restoration is then used as a proxy for its ecosystem service values.

### 5.4 Benefits transfer

All of the methods discussed above are appropriate when analysts have the resources and time to complete original valuation studies. However, in many situations budgets for these studies or the requisite amount of time to complete them do not exist. In these situations, economists use a technique known as benefits transfer to use values obtained from original studies in other, similar settings.

For example, the annual value of fisheries provided by a particular river segment can be approximated by the value calculated for another nearby segment of similar length in the same

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33 Kaval, 2010, Note 28.
watershed. Or the per acre value of non-timber forest products in one area can be applied to the same forest type elsewhere in the region. In using the benefits transfer technique, great care must be given to ensure that (1) both sites are as identical as possible ecologically speaking; (2) there are no major differences in use patterns – i.e. one in an urban area, one in a rural area; (3) the same service is valued in both situations, and (4) values that are transferred in are calibrated to account for inflation, changes in exchange rates, purchasing power parity, and other economic and demographic factors that may influence the relevancy of the original valuation estimate to the new analysis.34

6.0 Duty to consider avoided costs of the Chuitna coal mine

Another economic effect important to ADNR’s public interest determination is the effect of precluding “alternate uses of water that might be made within a reasonable time” if the application for reserved water is granted.35 The economic concept here is the concept of opportunity costs. Opportunity costs are simply the net economic benefits forgone by choosing one use of a resource over another. In particular, “[t]he opportunity cost of using an input to implement a policy is its value in its best alternative use.”36

Opportunity costs can be positive (and thus registered as a cost of the decision) if the precluded uses generate more economic benefits than costs, or negative if the precluded uses generate more economic costs than benefits. In the latter situation, preclusion leads to cost savings, a form of economic benefit commonly referred to as “avoided costs.” In a nutshell, “[c]osts avoided represent what you don’t have to pay because of the action you have taken.”37 Importantly, “a negative opportunity cost implies that the action taken is better than all alternatives.”38

In this case, preclusion of the Chuitna coal mine by a grant of instream flow rights to CCC will avoid the substantial litany of costs enumerated in CSE’s 2011 analysis of net public benefits associated with mine development.39 In that analysis, we determined that taking all known public and private costs into account, developing the mine would represent a net economic loss to the public of $57.23 billion to $75.27 billion depending on the price scenario for coal purchased from the mine on Asian markets and other value assumptions. These avoided costs are discussed in more detail later in this report.

7.0 A critique of the DNR valuation

Despite the clear linkages between ADNR’s public interest standard and the framework offered by ecosystem services, the agency concentrated on one aspect of a single service – the ex-vessel value of the presumed adult coho population. To meet its obligations to represent the economic interests of all Alaskans, ADNR should quantify the full range of ecosystem service values associated with the Middle Creek watershed using readily available information and methods at the agency’s disposal. The following section summarizes the problems with ADNR’s limited analysis to date.

7.1 Exclusion of values for most goods and services

The analysis excludes the vast majority of economic value associated with protection of Middle Creek. To reiterate: the ADNR valuation exercise concentrated on just a single provisioning service supported by Middle Creek – provision of coho salmon – and excluded valuation of all of the other goods and services associated with the wide range of uses described in Section 4.1, above. These include the value of all other direct uses of the watershed such fishing for species other than coho, recreation, hunting, and subsistence as well as indirect and non-use values such as carbon sequestration, clean water, and passive use values for pristine environments. Values can be assigned to all of these goods and services using one or more of the standard methods to do so described in Section 5.

For example, the value of all fish, game, birds and wild plants harvested for subsistence can be assigned a value based on the replacement cost method (which asks what the value of market substitutes are) in line with regular valuation assessments conducted by the Alaska Department of Fish and Game, Division of Subsistence. Using a replacement cost range of $4.00 to $8.00 per pound the statewide value of subsistence harvests in 2012 was estimated to range between $201 to $402 million.\(^\text{40}\) As previously discussed, passive use values for wild salmon in Upper Cook inlet have been estimated to be $3.98 (2010 dollars) per fish.\(^\text{41}\) The value of all ecosystem services can be estimated using the benefits transfer technique to apply per-acre values to each of Middle Creek’s vegetation communities (see below). Thus far, ADNR has focused on a single ecosystem service value and has ignored others that can easily be quantified.

7.2 Valuation of the coho catch is based on the wrong method

For the single ecosystem service ADNR valued, the valuation method is wrong. Assume, for now, that the data on the annual survival rate (246 to 1,789 coho) is correct and that all of the annual catch (123 to 781) is associated with commercial or subsistence fishing and that there are no other fish caught of value in the stream. In this case, the choice of ex-vessel price as a measure of value is erroneous. The correct method for valuing commercial and subsistence goods is to apply market prices because these reflect the true societal willingness to pay for the goods or the true

\(^{40}\) Division of Subsistence. 2014. Subsistence in Alaska: A Year 2012 Update. Anchorage, AK: Alaska Department of Fish and Game.

\(^{41}\) Helvoigt et al., 2010, Note 19.
replacement value of those caught for subsistence.42 For coho in the Anchorage market, prices right now are running right now about $10 per pound. The $0.91 per pound value used by ANDR is thus a gross underestimate.

But all of the catch derived from Middle Creek is not commercial or subsistence. Sport fishing likely makes up a significant share of the value of the fishery supported by Middle Creek. This is an important distinction because the method for valuation of sport fishing is much different. As noted by Bingham (2015), “[t]he value to sport anglers of a fish harvested in the recreational fishery is not directly comparable to the value in the commercial fisheries.”43 It is based on the consumer surplus or net economic value (NEV) of fishing trips. NEV is simply the difference between what anglers are willing to spend on a fishing trip over and above what they do pay. The NEV of sportfishing in Alaska has been well studied.

One of the most rigorous and often-cited studies estimated “NEVs from $817 per nonresident trip targeting salmon in remote sites to $34 per resident trip for road-accessible stocked waters.”44 The upper bound translates into $1,220 in today’s dollars, and should be used in the evaluation of Middle Creek’s sport fishery value.

The ADNR method also fails to use the correct analysis period. The choice of a 25-year analysis period is wrong because the damage to the Middle Creek fishery will extend well beyond the life of the mine. There are no precedents for replacing a salmon fishery once mined, so the safe assumption is to model the loss well into the future. At minimum, the analysis period should be set at 50 years.45

Finally, there is also substantial evidence that ADNR presented biased estimates of both the coho survival rate and corresponding catch. As noted by Bingham (2015), previous surveys estimated a survival rate of 1,983 to 2,313 adult coho per year and noted that these were likely conservative.46 If the same catch percentages hold as in the ADNR memo, this would translate into a catch of roughly 1,000. This makes a big difference to the estimate of value, as shown below.

42 “Market price-based approaches are most often used to obtain the value of provisioning services, since the commodities produced by provisioning services are often sold on, e.g., agricultural markets. In well-functioning markets preferences and marginal cost of production are reflected in a market price, which implies that these can be taken as accurate information on the value of commodities. The price of a commodity times the marginal product of the ecosystem service is an indicator of the value of the service, consequently, market prices can also be good indicators of the value of the ecosystem service that is being studied” – from The Economics of Ecosystems and Biodiversity (TEEB): The Economic and Ecological Foundations. Available online at: http://www.teebweb.org/our-publications/teeb-study-reports/ecological-and-economic-foundations/.
45 See, e.g. Talberth and Branosky, 2011, Note 39.
46 Bingham, 2015, Note 43.
7.3 Failure to quantify the avoided costs of the Chuitna coal mine

This duty was discussed in Section 6, above. Preclusion of the Chuitna coal mine by a grant of instream flow rights to CCC will avoid the substantial litany of costs enumerated in CSE’s 2004 analysis of net public benefits associated with mine development. Below, we discuss the likely magnitude of these costs in today’s dollars.

8.0 Likely magnitude of missing values

ADNR has access to peer reviewed methods and sources of information to correct these deficiencies. By doing so, the true value of granting CCC’s instream flow application will become apparent and reflect values that are astronomically greater than the limited analyses completed to date on just one small sliver of economic value. The following figures are indicative of the range of values that Middle Creek’s ecosystems provide in their natural state.

8.1 Value of wild coho, market replacement prices: $3.3 million to $3.9 million.

As noted above, ADNR incorrectly uses the exvessel value rather than market price and so underestimates the true worth of surviving adult coho by a factor of 10 or more. Moreover, ADNR uses a biased estimate of the adult survival rate and an arbitrarily short analysis period of 25 years. Using the current market price (paid by households) of $10 per pound, a survival rate of 1,983 to 2,313 fish\textsuperscript{47}, the ADNR value of 6.52 pounds per fish and an analysis period of 50 years translates into a present value worth of $3.3 million to $3.8 million. ADNR’s estimate was $36,470 to $265,219.

8.2 Value of wild coho, passive use: $222,967 to $260,071.

As discussed previously Helvoigt et al. (2010) estimated Alaska’s annual marginal non-use willingness to pay for a Upper Cook Inlet salmon to be $3.98. This reflects the intrinsic or passive use values Alaskan’s place on preserving wild fish and their habitat. This translates into a value of $4.37 in today’s dollars. Over a 50-year period this equates to a value of $222,967 to $260,071. This value is over and above the value of these fish in terms of their value to consumers.

8.3 Net economic value of sport fishing: $10.4 million to $12.1 million.

An updated per-trip NEV for salmon at remote locations based on Duffield et al. (2002) is equivalent to $1,220 in today’s dollars. That same study estimated salmon catch per trip ranging from 3 to 10, with the lower values associated with the most remote locations. If we assume that (1) roughly half the catch is sport fishing related; (2) catch per trip is on the low end, or 3 salmon and (3) model the benefits as before with a 3% discount rate and a 50-year time horizon, the value of coho sportfishing ranges from $10,374,498 to $12,100,965. This is probably conservative, as it does not account for sportfishing trips to take other species. To more

\textsuperscript{47} Again, these figures are discussed in Bingham (2015) and are indicative of a more reasonable estimate than those contained in ADNR’s analysis. We use these in subsequent calculations but recognize they are not definitive.
accurately estimate even this one resource, ADNR could determine the proportion of the catch that is sport related and value it in accordance with standard NEV methods using NEV data from around the region.

8.4 **Ecosystem service values based on Earth Economics study:** \$1.4 billion to \$3.5 billion.

By granting CCC’s application development of the Chuitna coal mine will be precluded. This will not only benefit Alaskans by protecting the immediate stream corridor along Middle Creek but the entire watershed of Middle Creek since it is slated for development and will otherwise be damaged by the mine and associated infrastructure. Thus, ADNR’s analysis of benefits of the application must include an analysis of the ecosystem service benefits that are generated by all lands and waters in the 9,126-acre watershed.

Fortunately, there has been a recent and comprehensive study nearby that can be used as a basis. This was a study prepared by Earth Economics for the 15 million acre Matanuska-Susitna watershed. Earth Economics found that the value of 13 ecosystem services produced by 10 land cover types ranges from \$20 to \$51 billion in economic value each year.\(^{48}\) This translates into an average value of \$1,702 to \$4,284 per acre per year across the basin.

The Earth Economics study used the figures reported in Table 3 (updated to 2015 values) as a basis for valuation of each of the land cover types that are also present in the Middle Creek watershed. They range from a low of \$90 per acre for mixed forest (including spruce-birch) under the low price scenario to a high of \$36,106 for wetlands under the high price scenario. These compare well with other values reported in the literature, and in fact in many cases are conservative.\(^{49}\)

Applying the per-acre values in Table 3 to the vegetation profile from Table 1 and then calculating the present value over 50 years yields a benefit estimate of \$1,424,658,380 for the low case and \$3,452,821,042 for the high case. This represents an annual value of between \$55.4 and \$134.2 million. Not all of the ecosystem services considered by Earth Economics may be present for ecosystems in the Middle Creek watershed, nonetheless, the magnitude of these benefit estimates underscores the imperative for ADNR to take ecosystem service valuation into account. Otherwise, ADNR will ignore the vast majority of benefits from a grant of the CCC application.

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\(^{49}\) One recent nationwide study, for example, found that the range of ecosystem service benefits from wetland mitigation to be in the order of \$5,000 to \$70,000 per year. See: Adusumilli, Naveen. 2015. “Valuation of ecosystem services from wetlands mitigation in the United States.” Land 4(1): 182-196; doi: 10.3390/land4010182. These values are for constructed wetlands. Natural wetland values are generally much higher and so the EE values are conservative.
Table 3
Ecosystem Service Values for the Middle Creek (Stream 2003) Watershed*
(Totals represent present value over 50 years at a 3% discount rate)

<table>
<thead>
<tr>
<th>Land cover</th>
<th>Acres</th>
<th>$/acre low</th>
<th>$/acre high</th>
<th>PV low</th>
<th>PV high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed forest</td>
<td>3,292.76</td>
<td>$89.88</td>
<td>$340.26</td>
<td>$7,614,816</td>
<td>$28,827,517</td>
</tr>
<tr>
<td>Coniferous forest</td>
<td>72.64</td>
<td>$98.44</td>
<td>$379.85</td>
<td>$183,990</td>
<td>$709,961</td>
</tr>
<tr>
<td>Deciduous forest</td>
<td>59.71</td>
<td>$80.25</td>
<td>$299.60</td>
<td>$123,281</td>
<td>$460,249</td>
</tr>
<tr>
<td>Shrub/scrub</td>
<td>954.29</td>
<td>$206.51</td>
<td>$274.99</td>
<td>$5,070,599</td>
<td>$6,752,041</td>
</tr>
<tr>
<td>Riparian buffer</td>
<td>451.00</td>
<td>$391.62</td>
<td>$18,768.87</td>
<td>$4,544,407</td>
<td>$217,796,287</td>
</tr>
<tr>
<td>River</td>
<td>37.00</td>
<td>$468.66</td>
<td>$11,798.89</td>
<td>$446,165</td>
<td>$11,232,558</td>
</tr>
<tr>
<td>Meadows</td>
<td>833.89</td>
<td>$19.26</td>
<td>$255.73</td>
<td>$413,238</td>
<td>$5,486,878</td>
</tr>
<tr>
<td>Wetlands</td>
<td>3,424.71</td>
<td>$15,959.05</td>
<td>$36,106.08</td>
<td>$1,406,261,885</td>
<td>$3,181,555,551</td>
</tr>
</tbody>
</table>

Totals: $1,424,658,380 $3,452,821,042

*Source: Based on updated per-acre values reported in Earth Economics (2010)

8.5 Instream flow benefits: $183.4 million to $436.6 million.

Another way economists have estimated ecosystem service values in particular watersheds is to concentrate on the benefits provided by river flows—most importantly for recreation, fishing, and other direct uses including domestic, agricultural, or industrial water supply. Such studies also capture the passive use values for maintaining river flows that may exist in a larger population regardless of actual use of the river.

This is a more limited approach than ecosystem service valuation for entire watersheds, but is nonetheless informative. It requires calculating values on a cubic feet per second (Cfs) or acre-foot basis for multiple flow benefits including recreation, wildlife, fish, cultural and passive use.

In a study of the benefits of instream flow protection in the Poudre River in Colorado, Loomis (2008) followed federal benefit-cost procedures by measuring economic benefits as the amount that households would pay to maintain the current flows.50 Using federally recommended dichotomous choice contingent valuation methodology, the median willingness to pay (WTP) of Fort Collins residents was found to be $234 per year. This represents annual value of water for instream flow of $171 to $255 per acre-foot during the April to September 6th time period. Another study addressing flow through the Glen Canyon Dam was conducted nationally through a contingent valuation survey and found a mean willingness to pay of $506.92 per acre-foot.51 There have been few instream flow studies in Alaska, but there is no reason to assume that these broad benefits associated with instream flow in Middle Creek and the Chuitna River would not apply and be within a comparable range.

To illustrate the importance of taking instream flow values into account, we can use the Loomis (2008) and Welsh (1997) estimates as lower and upper bounds. Updating to current dollars yields $213.14 per acre-foot as the low value and $564.37 as the upper end. Applying these to the annual acre-foot equivalent\(^{52}\) being adjudicated in the CCC application and then taking the present value of these benefits over 50 years yields the benefit estimates shown in Table 4: $183,443,288 to $436,577,079. ADNR’s evaluation of the benefits of CCC’s reservation should include at least some marginal benefit figure for each acre-foot reserved based on values reported in the published literature.

Table 4

**Instream Flow Values for the Middle Creek (Stream 2003) Watershed**

(Totals represent present value over 50 years at a 3% discount rate)

<table>
<thead>
<tr>
<th>Reach</th>
<th>Mean Cfs</th>
<th>Acre-feet/yr</th>
<th>$/acre-ft low</th>
<th>$/acre-ft high</th>
<th>PV low</th>
<th>PV high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>25.71</td>
<td>18,626</td>
<td>$237.14</td>
<td>$564.37</td>
<td>$113,647,586</td>
<td>$270,470,137</td>
</tr>
<tr>
<td>Middle</td>
<td>9.00</td>
<td>6,520</td>
<td>$237.14</td>
<td>$564.37</td>
<td>$39,782,147</td>
<td>$94,677,617</td>
</tr>
<tr>
<td>Main</td>
<td>6.79</td>
<td>4,919</td>
<td>$237.14</td>
<td>$564.37</td>
<td>$30,013,555</td>
<td>$71,429,325</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$183,443,288</td>
<td>$436,577,079</td>
</tr>
</tbody>
</table>

\(^{*}\)Source: Based on updated per-acre/ft values reported in Loomis (2008) and Welsh et al. (1997)

8.6 Avoided costs of the Chuitna coal mine: **$58.78 billion to $78.01 billion.**

In 2011 CSE conducted a preliminary net public benefits (NBP) evaluation of the Chuitna coal mine taking all public and private benefits and costs into account. The NBP analysis was conducted in accordance with standard federal procedures and yielded estimates of the project’s net present value and benefit cost ratio for four price scenarios and two delivered coal price scenarios to Asian markets. The analysis indicated that costs will exceed benefits by a large margin representing a net present value loss of between $57.23 and $75.27 billion over a 50 year analysis period. Social costs were determined to range between 193% and 604% of market prices, a finding that corroborates the range published in the academic literature. More recent market information suggests that the loss will be closer to the top end of this range since market prices are falling fast. As noted by the New York Times, “[m]arket forces have accomplished in just a few years what environmentalists and social advocates have struggled for decades to achieve. Coal prices have plunged about 70 percent in the last four years.”\(^{53}\) Another recent review of Asian coal markets and price structures concludes “[t]he Chuitna coal project would

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\(^{52}\) The cubic-feet reservation per month figures reported by ADNR can be converted to annual acre-feet equivalents by a number of useful online tools. We used the tool available here: [http://www.convertunits.com/from/%28cubic+feet%29+per+second/to/%28acre+feet%29+per+year](http://www.convertunits.com/from/%28cubic+feet%29+per+second/to/%28acre+feet%29+per+year).

serve little purpose in this shrinking [coal] market over the next several decades. There is no need for the mine and no price structure to support it.\textsuperscript{54}

The three most significant social costs identified included carbon emissions damage ($17.26 billion), air pollution damage ($53.09 billion) and loss of ecosystem services ($2.08 billion). Ecosystem service damages were estimated before the Earth Economics study was published, but are nonetheless remarkably consistent with the values implied by that study, falling squarely within the rage of benefits reported in Table 3 ($1.4 to $3.5 billion).\textsuperscript{55}

Including damages to ecosystem services in this avoided cost calculation, however, would amount to double counting if ecosystem service benefits are also considered, so a more valid assessment of avoided costs from the mine would exclude them. But if the avoided cost calculation rests on its own, then ecosystem service damages should be considered. For this preliminary assessment, we exclude ecosystem service damages (since we report ecosystem service benefits in Table 3) and update the remaining avoided cost figures to current values. This yields an avoided cost estimate of between $58.78 billion and $78.01 billion, which represents the enormous economic value to the public of leaving the coal beds untouched.

**Summary and conclusions**

In making a public interest determination associated with Chuitna Citizens Council’s application to reserve instream flow in Middle Creek (Stream 2003) ADNR has not ensured that all significant costs and benefits are considered. In this case, the cursory assessment of just one small type of benefit – the market value of coho – represents a small amount compared to the vast ecosystem service values that the 9,126-acre Middle Creek watershed generates for Alaskans on an annual basis.

These ecosystem service values include those associated with a wide range of direct uses such as hunting, fishing, and subsistence foods as well as passive use values for maintaining Alaska’s pristine watersheds. Together, they are likely to generate between $55.4 million to $134.2 million in value each year. ADNR has, at its disposal, all of the methods and sources of information needed to produce credible estimates of ecosystem service benefits for the Middle Creek watershed and break those benefit estimates out into sub categories of interest such as those associated with coho, sportfishing and instream flow as demonstrated above.

ADNR also has a duty to consider the significant avoided costs associated with a grant of CCC’s application. Should that application be granted, the public would be spared the enormous social and environmental costs associated with development of the Chuitna coal mine – avoided costs that are measured in the tens of billions.


\textsuperscript{55} The CSE (2011) estimates were based on damages, and the Table 3 (and Earth Economics) estimates based on benefits, but the two should be similar since the value of damages from the mine should be roughly equal to the annual ecosystem service benefits of keeping Middle Creek and the rest of the project area intact.
ADNR has failed to consider the immense ecosystem service values of the Middle Creek watershed and the avoided costs of the Chuitna coal mine in its public interest evaluation of CCC’s application.
Population diversity and the portfolio effect in an exploited species

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Population diversity and the portfolio effect in an exploited species

Daniel E. Schindler¹, Ray Hilborn¹, Brandon Chasco¹, Christopher P. Boatright¹, Thomas P. Quinn¹, Lauren A. Rogers¹ & Michael S. Webster²

One of the most pervasive themes in ecology is that biological diversity stabilizes ecosystem processes and the services they provide to society⁵⁶, a concept that has become a common argument for biodiversity conservation⁷. Species-rich communities are thought to produce more temporally stable ecosystem services because of the complementary or independent dynamics among species that perform similar ecosystem functions⁸. Such variance dampening within communities is referred to as a portfolio effect⁹ and is analogous to the effects of asset diversity on the stability of financial portfolios⁴. In ecology, these arguments have focused on the effects of species diversity on ecosystem stability but have not considered the importance of biologically relevant diversity within individual species. Current rates of population extirpation are probably at least three orders of magnitude higher than species extinction rates¹⁰, so there is a pressing need to clarify how population and life history diversity affect the performance of individual species in providing important ecosystem services. Here we use five decades of data from Oncorhynchus nerka (sockeye salmon) in Bristol Bay, Alaska, to provide the first quantification of portfolio effects that derive from population and life history diversity in an important and heavily exploited species. Variability in annual Bristol Bay salmon returns is 2.2 times lower than it would be if the system consisted of a single homogeneous population rather than the several hundred discrete populations it currently consists of. Furthermore, if it were a single homogeneous population, such increased variability would lead to ten times more frequent fisheries closures. Portfolio effects are also evident in watershed food webs, where they stabilize and extend predator access to salmon resources. Our results demonstrate the critical importance of maintaining population diversity for stabilizing ecosystem services and securing the economies and livelihoods that depend on them. The reliability of ecosystem services will erode faster than indicated by species loss alone.

The recent focus on ecosystem-based management of renewable resources emphasizes species interactions and how these are affected by human activities within exploited ecosystems. However, there is growing recognition that population diversity within exploited species can contribute to their long-term sustainability and should be incorporated more explicitly into management and conservation schemes¹¹,¹². For example, it has been argued¹³ that population diversity reduced the temporal variability of sockeye salmon fisheries in Bristol Bay because of complementary dynamics in different components of the stock complex. Similar phenomena are now appreciated qualitatively in other marine ecosystems¹⁴. However, at present there are neither quantitative estimates of the strength of portfolio effects produced by population and life history diversity in exploited species, nor an objective assessment of the benefits of population diversity to human economies and ecosystem services in general.

From 1950 to 2008, sockeye salmon supported the most valuable fisheries in the United States (landed value, US$7,900,000,000), and 63% of the associated revenue came from Bristol Bay (see Supplementary Information for details). The total economic value of this fishery is considerably higher when considering the retail, cultural and recreational value of these fish. Income from sockeye salmon in Bristol Bay is the major source of personal income for most Bristol Bay communities, and landing taxes provide the major funding for local school districts. Thus, the interannual reliability of this fishery has critical and direct consequences for the livelihoods of people in this region.

Population diversity within the stock complex of Bristol Bay sockeye substantially reduces the interannual variability experienced by the commercial fishery, which intercepts sockeye salmon as they enter each of the nine major rivers of this region (Fig. 1a). Each river stock contains tens to hundreds of locally adapted populations distributed among tributaries and lakes (Fig. 1b and Supplementary Fig. 1). This remarkable diversity in sockeye reflects their ability to thrive in a wide range of habitat conditions, the reproductive isolation of populations by precise homing to natal spawning sites, and their capacity for microevolution¹⁵. Thus, the Bristol Bay sockeye fishery integrates across substantial population diversity both within and among watersheds.

Annual sockeye returns to the Bristol Bay stock complex were considerably less variable (coefficient of variation (standard deviation divided by mean), CV = 55%) than those observed for individual rivers (average CV = 77%; Fig. 1c) for 1962–2008. Annual returns to individual populations spawning in streams of the Wood River system, where long-term detailed population assessments are available (Fig. 1b), were more variable (average CV = 95%) than both the aggregate of these streams (CV = 67%) and the total returns to the Wood River (CV = 60%; Fig. 1c). Thus, annual sockeye returns become increasingly more stable across the complexity hierarchy ranging from individual spawning populations to stocks associated with the watersheds of major rivers and, eventually, to the regional stock complex of Bristol Bay.

The degree of temporal covariation among portfolio assets controls the strength of portfolio effects⁸,¹⁴; the buffering effects of asset diversity on variability of the aggregate portfolio become weaker as asset dynamics become more synchronous. Analysis of the covariation among river stocks and among stream populations (that is, the analogues of assets in an investment portfolio) showed that annual sockeye returns were only weakly synchronous (and some negatively correlated) both within and among the watersheds of Bristol Bay. This lack of synchrony among populations of Bristol Bay sockeye occurred despite many commonalities in their migration corridors, nursery habitats and seasonal timing of migrations between freshwater and marine environments. Furthermore, strong shifts in climatic conditions...
If portfolio components in Bristol Bay fluctuated fully independently of one another, the expected CV would be only marginally lower (42% for rivers, 38% for Wood River tributary populations) than is currently observed (55% for rivers, 67% for tributary populations). The CVs of the dominant age classes at each level of spatial aggregation considered earlier were respectively 44%, 42% and 69% higher than the variabilities observed in Bristol Bay sockeye, both among major rivers and within individual watersheds, are derived from the weakly synchronous population dynamics among the components of this stock complex. If portfolio components in Bristol Bay fluctuated fully independently of one another, the expected CV would be only marginally lower (42% for rivers, 38% for Wood River tributary populations) than is currently observed (55% for rivers, 67% for tributary populations).

Life history diversity further buffers the variability of the sockeye stock complex. Most Bristol Bay sockeye spend one to two years rearing in fresh water and one to three years in the ocean as they complete their life cycles (Fig. 1d). This staggered age structure reduces variation in recruitment because it reduces the probability that all individuals in a cohort of siblings will encounter unfavourable environmental conditions over the course of the life cycle. To assess the effect of age structure diversity on variability, we compared the CV of total annual returns (above) with the CV observed within the two dominant age classes at each level of spatial aggregation considered earlier (Supplementary Fig. 3). The CVs of the dominant age classes in stream populations, river stocks and the Bristol Bay stock complex were respectively 44%, 42% and 69% higher than the variabilities observed at these spatial scales for the diversified population age structure (Fig. 1c). In sum, if the dynamics of Bristol Bay sockeye returns were characterized by the most simplified spatial and life history portfolio (that is, dominant age classes in the average stream population), they would be about 2.2 times more temporally variable (CV = 119%) than is currently observed for the Bristol Bay stock complex with its full complement of population and life history diversity. Furthermore, we assumed that fishery management would resemble the current system, in which the management goal is to allow approximately 10,000,000 fish onto the spawning grounds per year; returns in excess of 10,000,000 are harvested, and no fishing is allowed in years when fewer than 10,000,000 sockeye return. Given the current variability of the Bristol Bay stock complex, this picture translates into a complete fishery closure less than four times per century (Fig. 2). If Bristol Bay sockeye lacked the dampening effects population and life history diversity provide, complete fishery closures would occur every two to three years (Fig. 2). Thus, the net result of losing population and life history diversity could be a tenfold increase in the frequency of fishery closures, generating considerable hardship for people who rely on consistent annual returns for their livelihoods. A full assessment of the economic implications of such increased interannual variability resulting from loss of population and life history diversity would be valuable, but the necessary livelihood and economic data are lacking at present.

In addition to sustaining a valuable marine fishery, sockeye also support a diverse array of well-documented ecosystem processes and services in the watersheds where they spawn17,18 (Supplementary

![Figure 1](Image 130x548 to 465x733)
Information). Sockeye release substantial quantities of productivity-limiting nutrients following their post-spawning death21, and are the dominant food source for a community of mobile predators and scavengers in freshwater and terrestrial ecosystems. These species perform important ecosystem functions such as dispersing salmon-derived nutrients from spawning sites to the broader landscape8,20,21. Like commercial fisheries, many of these consumers are mobile and can capitalize on spatial variation in sockeye resources associated with the dynamics of individual populations within each river system. Using data on the number of spawning fish observed on the spawning grounds (the ‘escapement’), the average CV observed for streams was 82% whereas that for their aggregate was 46% and that for the entire Wood River was 50%. Thus, consumers able to capitalize on high-density sockeye populations experience substantially less interannual variation in salmon resources than they would if they focused on individual stream populations or if population dynamics within the stock were highly synchronous.

The life history diversity observed in the seasonal timing of migration and spawning among populations further enhances many ecosystem services by extending the seasonal availability of salmon resources to the fishery and watershed food webs (Fig. 3). For example, in a typical commercial fishing season 90% of the catch is taken in about 16 days, yet the midpoints of sockeye migration to the respective fishing districts vary over a range of about 13 days (Fig. 3a). This variation in migration timing allows the fishing fleet to assess relative abundance of sockeye among districts and redirect effort to capture fish from multiple districts within a season. If seasonal migration timing were more synchronous among districts, the window of opportunity to capture sockeye would be more constrained and the capture and processing fleet more easily saturated at the peak of the run. Seasonal access to sockeye by mobile predators is similarly extended because of staggered spawn timing among tributary and lake populations (Fig. 3b and Supplementary Fig. 3). Most sockeye populations are vulnerable to predators and scavengers in individual spawning habitats for approximately one month each year. However, salmon are present for over 2.5 months in spawning habitats throughout the Wood River watershed (Fig. 3b), owing to variation in the spawn timing among populations. Thus, watershed consumers of salmon and the ecosystem services they provide (for example trout fishing and wildlife viewing) also benefit from the variation in spawn timing, which represents one of many dimensions of life history variation in this species13.

Although most large-scale fisheries probably integrate across considerable intraspecific diversity in a manner similar to that described here, this ‘stock structure’ is usually ignored by management focused on numerically dominant stock components12. Variation in the population dynamics of Bristol Bay sockeye is easy to monitor because of spatial separation among stock components resulting from the homing tendencies within populations. However, similar population diversity, although more cryptic, may exist and be equally important in other species22, a possibility supported by the growing recognition of homing tendencies in marine and freshwater fish stocks23,24. There is no reason to believe that population and life history diversity are any less important in other aquatic or terrestrial species that are focuses of exploitation or conservation.

The portfolio effects in the Bristol Bay sockeye stock complex are a characteristic of a landscape with a largely undisturbed habitat, natural hydrologic regimes and neither invasive species nor artificial propagation of salmon in hatcheries, combined with sustainable fishery exploitation. In contrast, in the southern end of their range, Pacific salmon populations have declined substantially owing to the cumulative impacts of heavy exploitation, habitat loss, climate change, hatchery dependence and hydropower development. Recent assessments show that 29% of 1,400 populations of Pacific salmon in the US Pacific Northwest and California have been extirpated since European contact25. What is underappreciated is that extant stocks in highly
affected watersheds have also lost some of the stabilizing portfolio effects that we observe in Bristol Bay.  

Although ecosystem management schemes commonly map the habitat requirements of individual species, it is rare to consider the heterogeneity and disturbance regimes that maintain population and life history diversity in ecosystems. In the case of fisheries management, minimizing the homogenizing effects of hatcheries on genetic diversity and protection of weak stocks from overharvesting in mixed stock fisheries will be required to maintain the diversity that stabilizes variance in returns. Without this broader framework for conserving the roles of individual species, the resilience biodiversity provides to ecosystems will deteriorate well before individual species are extirpated.

**METHODS SUMMARY**

Annual sockeye escapements to rivers were enumerated visually from towers on each of the Bristol Bay rivers by the Alaska Department of Fish and Game. Age composition of sockeye was estimated by subsampling approximately 50,000 fish from the fisheries and the escapement towers in each year. Total returns to each river were calculated as the sum of fisheries catch and the escapement to the spawning grounds. In fishing districts that capture fish from neighbouring rivers, age composition comparisons between the fishery catch and the escapement towers was used to assign harvested fish to the total annual return to each river. Stream-spawning populations of sockeye salmon in the Wood River system were monitored by two to four people who surveyed the entire extent of habitat suitable for sockeye spawning at least once per year at the peak of spawning activity. Otoliths were sampled annually from up to 220 fish from each steam to determine the age composition of the escapement. The total stream production for eight streams was calculated by accounting for the age- and year-specific vulnerabilities to the fishery and then adding estimated fishery interceptions back to the stream-spawning populations on the basis of the stream age composition in each year. Interannual variability was calculated as the CV for all situations considered.

**Full Methods** and any associated references are available in the online version of the paper at www.nature.com/nature.

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**Supplementary Information** is linked to the online version of the paper at www.nature.com/nature.

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**Author Contributions** D.E.S. designed and coordinated the project; R.H., B.C. and L.A.R contributed to the analyses; M.S.W. helped design the project; and all authors contributed to the writing.

**Author Information** Reprints and permissions information is available at www.nature.com/reprints. The authors declare no competing financial interests. Readers are welcome to comment on the online version of this article at www.nature.com/nature. Correspondence and requests for materials should be addressed to D.E.S. (deschind@uw.edu).
METHODS

River escapements were estimated by visual counts from towers located on either side of each of the Bristol Bay rivers by the Alaska Department of Fish and Game\textsuperscript{29}. Migrating sockeye were counted for 20 min each hour, split equally between the two sides of each river, and these figures were extrapolated into daily escapement estimates. Nine major rivers contribute to the Bristol Bay fishery. For the analyses in this paper, we have not included the populations in the Nushagak River, as these have only been enumerated for the past two decades. Ages (numbers of years in fresh water and in the ocean) of fish were determined by visual examination of scales or otoliths sampled in the escapement and in the fishery catches.

Stream-spawning populations of sockeye salmon have been monitored by the University of Washington since 1956 throughout the Wood River system. Stream surveys were conducted by two to four people who walked the entire extent of habitat suitable for sockeye spawning at least once per year at the peak of spawning activity, counting the live and dead sockeye. Otoliths were sampled annually from up to 220 fish from each steam to determine the age composition of the returns. The total stream production for eight streams was calculated by accounting for the age- and year-specific vulnerabilities to the fishery on the basis of samples collected in the fishery, and then adding estimated fishery interceptions back to the stream-spawning populations on the basis of the stream age composition in each year\textsuperscript{30}.

The interannual variability in total returns to Bristol Bay was compared with the variability observed in the total returns to each of the major rivers. The variability in the annual returns to each of the eight streams in the Wood River for which we had detailed age composition data, which could be used to apportion fishery catches to total annual returns, was compared to the interannual variability observed in total returns to the Wood River system as a whole. When considering services provided by sockeye in freshwater ecosystems, we assessed variability only for sockeye abundance in the spawning grounds for the eight stream populations (that is, not including fishery interceptions).

We calculated covariations among the numbers of sockeye that returned to each of the rivers or streams (Supplementary Fig. 2) as the Pearson correlation among all pairwise combinations of stocks or populations with a minimum of ten years of concurrent data. Because the time series were often positively autocorrelated, we used the method of ref. 31 to adjust the degrees of freedom in tests of significance for each pairwise correlation. Tests of statistical significance were two-tailed, with $\alpha = 0.05$.

MEMORANDUM

State of Alaska
Department of Fish and Game
Division of Habitat

TO: Michael Daigneault
Regional Supervisor
Central Region Office

DATE: July 28, 2014

PHONE NO: (907) 267-2113

FROM: Josh Brekken
Habitat Biologist

SUBJECT: Chuitna Coal Project Site Survey
Beluga, AK
July 15-17, 2014

On Tuesday, 15 July 2014, Kate Harper and I traveled to Beluga, AK to conduct fish and site surveys in an area proposed for development by PacRim Coal LP (PacRim) as the Chuitna Coal Mine. We arrived in Beluga around 8:00 am and traveled to the sites via helicopter (see Figure 1).

Our first stop was at a tributary of Lone Creek (N 61.163°/W 151.248°, see Figures 2 and 3), that PacRim Coal has proposed for off-site and alternative mitigation. This area is located outside of the proposed active mine area (southeast of mine area). We did not minnow trap or electro-fish at this location due to time constraints and because juvenile salmon have already been documented at this location. In their Working Draft Fish Protection Plan (Draft FPP) dated June 2014, PacRim identified this eastern tributary of lower Lone Creek for “Tributary Spawning and Rearing Habitat – Stream 2002”. According to PacRim’s Draft FPP, fish passage in this tributary system is currently being blocked by a series of beaver dams near its confluence with Stream 2002 (Lone Creek).

Proposed mitigation will remove blockages and ‘enhance’ the stream channel. However, baseline studies conducted by PacRim contractors in 2006 and 2007 documented juvenile coho salmon at this location, which was a baseline minnow trapping site (2002-4). However, this stream segment has not yet been nominated to the AWC. I have submitted a nomination form to extend the AWC catalog for salmon rearing habitat in this tributary. Fish surveys have not been conducted upstream of this minnow trap site.

The stream at this location is about 4-feet wide and 5-feet deep with emergent and overhanging vegetation. The habitat is suitable for juvenile salmon rearing and is being used by salmon species for rearing. The habitat is poor for salmon spawning (see Pictures 1-3). Flows in the channel are barely perceptible (although not measured) and the substrate is composed of thick silts and organics. The landscape has very little relief and the entire area is surrounded by a flat and boggy wetland.

Based on the previous documentation of juvenile salmon rearing, suitable rearing habitat upstream (potentially for another mile and a half), and the lack of permanent barriers, it is likely that salmon are rearing upstream of this location and additional fish surveys are recommended to fully document anadromous fish habitat in an area proposed for alteration as a mitigation alternative.
Figure 1. General site location figure. Blue lines are waterbodies listed in the AWC.
Figure 2. "Tributary Spawning and Rearing Habitat – Stream 2002" as proposed in PacRim's Draft FPP and location of July 15, 2014 site visit. Direction of stream flow is from the top of the page to the lower left hand corner.
Figure 3. "Tributary Spawning and Rearing Habitat – Stream 2002" as proposed in PacRim's Draft FPP and location of July 15, 2014 site visit showing photograph location and orientation. Direction of stream flow direction is from the top of the page to the lower left hand corner.
Photograph 1. Aerial view of area proposed for “Tributary Spawning and Rearing Habitat – Stream 2002” (looking southeast, 7/15/14).

Photograph 2. Ground view of area proposed for “Tributary Spawning and Rearing Habitat – Stream 2002” (looking downstream/southwest, 7/15/14).
Photograph 3. Aerial view of area proposed for channel augmentation as part of “Tributary Spawning and Rearing Habitat – Stream 2002” (looking southeast, 7/15/14).

We conducted an overflight of another area proposed for potential mitigation (Lake 5 Area, see Photographs 4 and 5) in the Stream 2003 (Middle Creek) drainage. This is an area that PacRim has indicated will be a primary mitigation area and they will conduct field work this summer to determine if site conditions are suitable for construction of spawning and rearing habitat. Baseline studies did not document any fish populations in this lake or wetlands, but the outlet stream has not been surveyed.
Photograph 4. Aerial view of the Lake 5 area proposed for habitat mitigation (looking east, 7/15/14).

Photograph 5. Aerial view of the southern edge of Lake 5 area proposed for habitat mitigation (looking east, 7/15/14).
Next, minnow traps were set in various locations near the headwaters of Stream 2003 (Middle Creek) with the intent to clarify conflicting details from PacRim’s baseline studies and to document fish populations. Ten minnow traps were baited with salmon roe and set in open water that was part of, or connected to, Lakes 3, 4, and 9 (see Figure 4).

After setting minnow traps, we traveled to a northeast tributary of Middle Creek to electrofish above the furthest extent of previous fish surveys. We began our survey at the uppermost minnow trap site (from baseline studies, 2003-12) and traveled upstream using a backpack electrofisher. Juvenile coho salmon and slimy sculpin were captured as we worked our way upstream. At 1500 we ended the survey, but the furthest extent of salmon distribution was not yet reached. A nomination to extend the distribution of coho salmon in the AWC has been submitted and additional fish surveys upstream are recommended based on suitable rearing habitat, lack of barriers, presence of juvenile salmon, and documentation of adult coho salmon spawning less than a half mile downstream of this location (see Figure 5). At about 1600, Kate Harper boarded a return flight to Anchorage.
Figure 4. Location of minnow traps set on July 15, 2014 (light blue outlines). The green line is the approximate location of the area to be mined and the dark blue lines identify waters currently listed in the AWC.
Figure 5. General location of fish surveys conducted from July 15-17, 2014 (upper Middle Creek). The blue line represents stream habitat already designated as important for salmon in the AWC. The orange and red lines depict stream and lake habitat that has been submitted for inclusion in the AWC based on captured coho salmon (7/15-7/17/14). The green lines depict stream habitat with fish populations unknown (not yet surveyed).
On Wednesday, July 16, I met Stormy Haught at the Beluga airport. After some site orientation and logistics, we traveled via helicopter to the fish survey area. Minnow traps were checked between 9 am and noon. Only one of the minnow traps contained fish. The minnow trap set at the outlet of Lake 9 contained 14 Dolly Varden between 112 and 144 mm fork length (see Photograph 6).

Photograph 6. Dolly Varden captured in Lake 9 outlet stream (7/16/14).

Next, we traveled back to the upper-eastern tributary of Middle Creek and began electrofishing upstream (northwest direction) of the uppermost minnow trap set during baseline studies. This tributary is shown in Figure 5 as the orange stream course that leads from Lake 4 (see Photograph 7). Juvenile coho salmon were very abundant in this tributary (all locations and habitat that were electrofished contained juvenile coho). Fork lengths of captured coho salmon ranged between 32 and 105 mm (see Photograph 8).
Photograph 7. Headwater tributary of Middle Creek (Stream 2003) that drains from Lake 4, 7/16/14.

Photograph 8. Coho salmon captured in Lake 4 outlet stream/headwater tributary of Middle Creek (7/16/14).
At 1500, we traveled via helicopter up to Lake 4 (see Photograph 9) to survey the lake and clarify some conflicting information from PacRim's baseline studies. On July 21, 2006, one juvenile coho salmon (41 mm FL) was captured in a minnow trap from this lake. On August 19, 2007, the lake was fished with a multi-mesh gillnet for 4 hours, and the biologist's field notes indicate that four rainbow trout (281 to 430 mm) were captured. However, the only fish picture provided with this sampling effort was clearly of a coho salmon, calling into question the proper identification of species in this lake for that effort. At 1530 we deployed a 120-foot long multi-mesh gillnet on the eastern shore of the lake. While the net soaked, we electrofished the outlet stream and continued to capture good numbers of coho salmon (<145 mm FL) in this small tributary nearly to the outlet of Lake 4. At 1715 we checked the gillnet. One coho salmon (~380 mm, fatality, see Photograph 10) and one Dolly Varden (~160 mm) were captured in the net. The net was stacked onshore and at 1830 we traveled back to Beluga for the night.

Photograph 9. Aerial view of Lake 4 (7/15/14, view to the west).
On Thursday, July 17, 2014 we traveled back to the fish survey sites via helicopter. The same gillnet was set in Lake 4 at 0930. While the net soaked, we traveled to the outlet stream of Lake 9 to electrofish this tributary of Middle Creek. Good numbers of coho salmon (<66 mm FL) were captured in all locations along this tributary from Middle Creek to the outlet of Lake 9 (see Photograph 10 and 11). Dolly Varden (<86 mm FL) and coastrange sculpin (45 mm) were also captured.
Photograph 10. Outlet stream from Lake 9 and tributary of Middle Creek (7/17/14).

Photograph 11. Coho salmon captured in Lake 9 outlet stream (7/17/14).
At 1500 we traveled back to Lake 4 to check the gillnet. Two coho salmon (375 and 425 mm, one fatality) were captured in the net (see Photograph 12). At 1530 we boarded the helicopter and traveled back to Beluga where we demobilized our gear, packed, and returned to Anchorage (me) and Palmer (Stormy).


These surveys documented anadromous fish populations in streams and lakes that were previously unsurveyed or that contained conflicting or limited baseline information. All of the areas that were surveyed completely during our visit contained coho salmon. Based on this fact, and the large amount of unsurveyed waterbodies in these watersheds, I believe the amount of anadromous fish habitat in the area has been under documented. Further fish investigations are needed to fully document the amount of anadromous fish habitat potentially impacted by proposed mining plans, including proposed alteration of functioning fish habitat for mitigation purposes.

Based on aerial photography, about 12 miles of stream habitat remains unsurveyed in the area proposed to be mined. We had intended to survey more of these areas, including some high gradient streams, but unfortunately did not have enough time to get on the ground at all of the planned locations. Visual observations of these higher gradient streams made during overflights suggest that at least some of the unsurveyed streams may be too steep to provide fish habitat. However, based on professional judgment, about 10 miles of stream habitat with the potential to support anadromous fish remain unsurveyed in the area proposed for mining. Most of these miles are part of small, headwater streams that are difficult to access due to thick vegetation (see Figure 6, green line segments). About 13 miles of stream habitat within the area proposed for mining have been documented as supporting anadromous fish (see Figure 6, blue line segments).
I have submitted complete applications for an additional 2.8 miles of coho rearing habitat in the Middle and Lone Creek drainages for inclusion in the AWC based on information from this field survey.

Figure 6. Stream habitat within the area proposed to be mined. The blue line represents stream habitat already designated as important for salmon in the AWC. The orange and red lines depict stream and lake habitat that has been submitted for inclusion in the AWC based on captured coho salmon (7/15-7/17/14). The green lines depict stream habitat with fish populations unknown (not yet surveyed).
Josh Brekken

ccc: A. Ott, ADF&G
     K. Harper, ADF&G
     S. Haught, ADF&G
     R. Kirkham, ADNR
     D. Graham, PacRim
     H. Firstencel, USACE
IN REPLY REFER TO:

AFWFO

Ms. Hanh Shaw
U.S. Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101

Re: Chuitna Coal Project-
Fish Information

Dear Ms. Shaw:

The U.S. Fish and Wildlife Service (Service) has been involved with the Chuitna Coal Project since late 2005 as part of the National Environmental Policy Act (NEPA), National Pollution Discharge Elimination System (NPDES), Clean Water Act (CWA) and Alaska Surface Coal Mining Control and Reclamation Act (ASCMCRA) processes. While we have been involved with all aspects of the project review, we have been particularly involved with and concerned about potential project impacts to fish resources in the Chuit River watershed due to the Service’s trust responsibilities and the severity of potential project impacts to those resources. This letter is intended to summarize our previous comments and concerns related to fish populations and fish habitat to assist the Environmental Protection Agency in their role as lead federal agency for this project.

We believe that the proposed project will result in significant adverse impacts to fish populations and habitat, and that the majority of these impacts cannot be avoided or minimized due to the inherent nature of coal strip mining. While we understand that reclamation will be required, we believe there is a high degree of risk and uncertainty associated with attempting reclamation of a complex watershed like the Chuit River system. We are concerned that area fish habitats and populations cannot be successfully reclaimed or restored to pre-project conditions. Therefore, the Service will recommend to the Environmental Protection Agency, the Corps of Engineers and the Alaska Department of Natural Resources that compensatory mitigation be required to offset losses to fish habitat and populations which cannot be avoided, as well as to account for the risk and uncertainty associated with attempted reclamation on such a large scale. Compensatory mitigation recommendations will be in addition to reclamation recommendations.
At this time, we are not providing comments on other aspects of the project and project related baseline studies, such as wetlands, vegetation, or wildlife. We have previously provided comments and attended several meetings on the recently submitted “Overwintering Sampling Plan for Chuitna Tributary 2003” dated September 24, 2007, so we are not providing additional comments at this time. As discussed in several meetings and teleconferences, in our view, this plan is significantly flawed; however, it is our understanding the Overwintering Sampling Plan has already been initiated against our recommendations and those of other federal and state agencies. We are concerned that not all baseline studies have yet been released. Because project components and designs, and potentially at risk resources are so interrelated, piecemeal submittal of project information makes providing meaningful comments and recommendations difficult.

Why Gather Adequate Information?

To properly assess and quantify project impacts to fish resources in the Chuit River drainage, and to develop sufficient mitigation and reclamation plans, the Service believes that adequate information on existing fish habitat, fish populations, water quantity, water quality, and riparian conditions must be gathered. We do not believe that the current level of information is adequate to allow a sufficient level of understanding of resources at risk, so that: 1) potential impacts can be quantified; 2) impacts can be avoided or minimized if practicable; 3) reclamation and monitoring plans can be developed; and 4) compensatory mitigation options can be described and assessed.

As stated in previous comments on the draft Aquatic Biology Baseline Report (April 2007 email from Service biologist Phil Brna to others involved with the project):

“The report presents information about results based on use of limited study methods, but the methods do not provide an adequate level of baseline aquatic information. There are two purposes for providing aquatic baseline information.

First, the information presented must be adequate to support the NEPA evaluation. Information must be presented which adequately describes all existing aquatic resources (fish, fish habitat, water quality, water quantity and sources, benthic macroinvertebrates (BMI)) present in project area streams and lakes so that potential project impacts can be assessed. Mitigation options, including avoidance, minimization, restoration and compensation, of project effects can then be described in the SEIS. Information must be adequate not only for stream 2003 but also for streams 2002 and 2004 and all stream reaches (including downstream reaches to the mouth of the Chuit River) and lakes which could be affected by any aspect of the mining operation.

Second, the information presented must be adequate to allow for design of "restoration" of fish habitat and populations in disturbed stream reaches. The information must provide an adequate baseline which can be used to assess whether
restoration is successful over-time, and it must allow for a prediction of the time required for successful and complete restoration to pre-project conditions. Control sites outside of any mined area must be considered so that success of restoration efforts can be separated from naturally occurring conditions.”

What Information is Needed?

We believe that detailed and specific information which “adequately describes all existing aquatic resources (fish, fish habitat, water quality, water quantity and sources, and BMI) present in project area streams and lakes” must be gathered. This includes the mainstem Chuit River, tributaries 2002, 2003, and 2004, Threemile Creek, and all potentially affected lakes. In addition, fish population and fish habitat information must be gathered for the remainder of the Chuit River watershed so that the contribution of areas affected by the project can be assessed relative to the larger system.

Our recommendations for specific and detailed information which must be gathered include to:

1. Quantitatively estimate population abundance and distribution of anadromous and resident fish species in all potentially affected project area streams and lakes, including downstream reaches for all fish life phases including spawning, rearing, and overwintering. Ideally, fish population and fish habitat information should be gathered for a minimum of five years so that uncertainty related to annual variability can be minimized. Five years is a normally recommended study period because it allows biologists to begin to understand population variability in anadromous fish populations, but 5 years may not be sufficient to evaluate variability of resident species. To obtain sufficient population estimates, various sampling methods including minnow traps, weirs, sonar, aerial surveys, radio tagging, PIT tags, electrofishing, gillnetting, fyke nets, and beach seines should be considered. As per recommendations of the Alaska Departments of Natural Resources, and Fish and Game, the preferred approach for estimating fish production is to establish juvenile and adult weirs at the mouths of tributaries 2002, 2003, and 2004. Additionally, a sonar site should be established on the Chuit River to estimate salmon escapements to the system.

2. Compare abundance of anadromous and resident fish within the project impact area relative to the remainder of the Chuit River drainage. Drainage wide information is also important to help understand the context of the project in terms of cumulative effects related to potential future mining. Tagging studies will be needed to understand stock structures and migratory patterns within the watershed.

3. Estimate populations for selected (index) fish species in a reference site(s) outside of the Chuit River drainage which can be used to measure the success of fish population and habitat restoration activities over the long-term.
4. Obtain specific information related to habitat preferences for all species over all life phases.

5. Conduct an instream flow study to determine how aquatic habitat availability will change as water inputs to area streams, lakes, and wetlands change. One of the greatest potential project impacts is altered stream flows. PacRim has not adequately demonstrated how water is entering area streams and lakes, the importance of baseflows, the locations of upwellings, or water temperatures. These water inputs are critical to overwinter survival, rearing habitat availability, and spawning success of all fish species. If baseflows, upwellings and temperature regimes cannot be restored, there is great risk that fish population and fish habitat reclamation efforts will fail. An instream flow study is needed on streams 2002, 2003, and 2004 as well as upstream and downstream on the Chuit River so that effects of the project on total habitat availability can be predicted. It is our understanding that existing project information predicts streamflow effects on a macro-scale but potential micro-scale changes in groundwater associated with mining activities cannot be predicted. For example, project information shows that baseflows predicted at the mouths of tributaries 2002, 2003, and 2004 will not change significantly from pre-project conditions. However, the models cannot predict where groundwater upwellings will occur even though these upwellings are critical to fish survival and productivity.

6. Develop a temperature model which is able to predict water temperature changes as a result of mining. Existing studies show that even small changes in water temperature can have significant impacts on fish populations and productivity (Quinn 2005).¹

Reclamation and Restoration

Detailed knowledge of fish populations and fish habitat present pre-mining is essential to properly establish goals, objectives, and reclamation performance standards for post-mining operations. Agencies, in consultation with the public, must establish broad goals and objectives based on an adequate understanding of resources present in and adjacent to the mining area. Performance standards will follow and they will be the details which drive required protection and reclamation plans. It is premature to concentrate on details of reclamation until we have an adequate understanding of existing resources, project design and sequencing, and potential project consequences. Any restoration goal needs to be consistent with applicable State and Federal regulations and the needs of the landowner and the effected public. The reclamation goal should be to recreate the natural complexity and diversity of conditions which existed pre-mining by restoring soils, water regimes, and topography so that pre-mine fish and wildlife habitats and populations can be restored. The project should result in no net loss of fish populations and habitat.

We are concerned that lakes, streams, wetlands, and fish populations impacted by this project cannot be restored in our lifetimes. Agencies and project proponents should jointly and clearly state the restoration goals but must also disclose that there is a real risk
that full restoration may not be possible. In our experience, the potential to restore degraded or destroyed fish populations and habitat is extremely limited and costly. Many experts agree that it is best not to damage a healthy system in the first place, because it may not be possible to restore fish and wildlife habitat and populations no matter how much time and money is available.

Thank you for the opportunity to provide comments and recommendations. If you have any questions regarding these recommendations, please contact project biologist Phil Brna at 271-2440, or by email at phil_brna@fws.gov.

Sincerely,

[Signature]
Ann G. Rappoport
Field Supervisor

cc: Hanh Shaw, EPA
M. Fink, ADF&G
T. Brookover, ADF&G
S. Maclean, ADNR
M. Marie, ADNR
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B. Buzby, ADNR
P. North, EPA
R. Stiles, PacRim

29 September 2014

EPA’s General Comments on the Revised Post-Mine Reclamation Plan Overview (dated August 2014) Conceptual Compensatory Mitigation Plan (CCMP) and Fish Protection Plan (both dated June 2014) for the proposed Chuitna Coal Project.

We regard the Fish Protection Plan as a component of the Compensatory Mitigation Plan that identifies several specific proposals to offset the loss of fish production capacity that would result from the direct impacts to anadromous streams within the mine’s excavation footprint.

Key points regarding the requirement for compensatory mitigation for the project’s direct impacts: First, compensation is required for all direct impacts to jurisdictional waters of the U.S. to the extent that it is appropriate and practicable. “Appropriate” in this context means commensurate with the level of impact. The impacts from some projects, such as those authorized by general permits, are so minimal that no compensation is warranted. We do not believe that to be the case here. “Practicable” means “available and capable of being done.” The CCMP provides no information indicating that compensation might be impracticable.

As stated above, direct impacts resulting from the discharge of fill must be compensated for. Secondary and cumulative impacts generally do not require compensation under 404. Secondary impacts, such as those from the discharge of aquifer drawdown water, result from associated project activities not regulated by 404, though compensation may be required by other agencies under different authority. Cumulative impacts result from the independent actions of other permittees. Cumulative impacts are not compensated for per se, but they have the effect of increasing the severity of the direct (and possibly secondary) impacts. The result is that the direct impacts would be compensated for at a higher rate due to the increased severity.

We have concerns about the efficacy of off-site compensation to reduce the level of impact below that which would cause or contribute to significant degradation. 43 CFR 230.10(c) provides that “no discharge of dredged or fill material shall be permitted which will cause or contribute to significant degradation of the waters of the United States.” Proposed discharges that cause or contribute to significant degradation as determined by the factual determinations contained in the 404(b)(1) Guidelines in spite of compensatory mitigation may not be authorized.

Although compensation may not be required for secondary and cumulative impacts, these impacts are explicitly evaluated during the significant degradation determination. The significance of the project impacts, direct, secondary, and cumulative, and whether these impacts might cause or contribute to significant degradation is never addressed in the CCMP.

This is understandable, as the CCMP is not a (b)(1) evaluation, but the restrictions on discharge contained within the CWA Section 404(b)(1) Guidelines [at 230.10] must be addressed at some point. The restrictions are independent and intended to be addressed sequentially. That is, the LEDPA for the overall project purpose is to be identified before the questions of whether the proposed discharge would cause or contribute to the violation of an applicable water quality standard or toxic effluent
standard are addressed. Similarly, the question of whether the proposed discharge would cause or contribute to significant degradation should be addressed prior to completion of a detailed compensatory mitigation plan.

230.10(c) prohibits the authorization of discharges that cause or contribute to significant degradation. 230.10(d) requires all practicable avoidance, minimization, and compensation of project impacts. These are independent restrictions and 230.10(c) is not “met” by skipping it and complying with 230.10(d). Due to the sequential nature of the Guidelines, a determination that the project would cause or contribute to significant degradation generally precludes discussion of compensatory mitigation. Compensatory mitigation is relevant for compliance with 230.10(c) only if specific compensation measures served to reduce the significance of project impacts.

Typical third-party compensation measures (i.e., purchasing mitigation credits from mitigation banks or In-lieu fee (ILF) program sponsors) “offset” impacts through functional transfer (i.e., from the impact to the mitigation site). For the majority of projects that do not result in significant degradation, functional transfer is appropriate and explicitly acknowledged in the Guidelines.

The situation changes if functional loss at the project site results in significant degradation. Since functional gain at the mitigation site does not reduce the severity of the impacts at the project site, the purchase of mitigation credits does not help a project to comply with 230.10(c).

Unlike the projects of mitigation banks and ILF program sponsors, permittee-responsible mitigation (PRM) projects are designed to offset specific impacts, and are therefore more likely to reduce the severity of project site impacts. The PRM proposed within the Fish Protection Plan appears intended to offset functional losses within the project footprint through functional gains within the watershed, with potential implications for compliance with 230.10(c). The EPA supports this conceptual approach.

The Fish Protection Plan focuses on that portion of the stream network documented as anadromous fish habitat. As mentioned above, however, all of the direct impacts to jurisdictional waters, both streams and wetlands, would need to be compensated for.

Both temporal and permanent losses of aquatic resource function may need to be compensated for. Temporal losses are those associated with the mine disturbance that are not permanent because successful post-mine restoration re-establishes the aquatic function. Permanent losses are those where post-mine restoration does not fully re-establish the aquatic function.

Direct compensation may not be required for projects with short-duration temporal losses. In such cases, permanent losses may be compensated for at a higher ratio to address the temporal loss. In this case, however, the temporal losses appear to be of sufficient duration as to be treated as permanent. The applicant’s groundwater modeling indicates that it may take fifty years or more for the aquifer to rehydrate after groundwater pumping ceases.
Though the mining activity and disturbance will proceed in phases as the mine cuts are advanced across the mine lease area, it appears as though even the shortest duration temporal losses will be of sufficient duration to warrant direct compensation.

If all of the aquatic resources in the mine footprint will suffer long-term temporal loss, compensating for the temporal loss would also offset any permanent losses. To some extent, this simplifies the issue of compensatory mitigation, as functional losses are addressed only once. There is no need to separately quantify the temporal and the post-restoration permanent losses.

We intentionally refer here to restoration rather than reclamation. Reclamation is intended to stabilize the mine site and support the post-mining land use. Reclamation activities may or may not include the restoration or establishment of specific aquatic resource functions. Restoration of aquatic resources is planned as a major component of post-mine reclamation, but it is the specific restoration actions that will result in aquatic function gains if they are successful.

We consider the distinction between reclamation and restoration to be significant. Actions that are taken as compensation are also distinct. Restoration by definition is a form of compensatory mitigation that results in gains of aquatic resource function, though not acreage. Reclamation could also include the establishment of aquatic resources, which would result in both acreage and functional gains. Reclamation itself is not directly related to compensation.

Section 1.5 of the CCMP relates mine reclamation with compensation. It states: “Concurrent reclamation is a required regulatory component of the coal mining process. Therefore, it is logical to measure the mine impacts on wetlands and streams as the mining advances and consider the reclamation that occurs as part of the mitigation for future mine advances.” We disagree with the final statement. Reclamation, whether required or not, does not necessarily result in gains of aquatic resource function.

And reclamation that includes restoration is typically considered as a minimization measure. The effective restoration of aquatic resources would result in a reduced level of, or perhaps even eliminate, permanent impacts. In order for aquatic resource restoration or establishment conducted during post-mine reclamation to be used as compensation, they would have to result in aquatic resource functional gains relative to the pre-mine condition.

As indicated in the CCMP, credits and debits are units of measure that represent the accrual or loss of aquatic resource function. To characterize them, as the CCMP also does, as representing gains and losses of habitat value, is a misleading oversimplification. The issue of credit generation is an important one. Per the Final Rule, the accrual of aquatic resource function (the “functional lift”) represented by a credit is determined by a function or condition assessment that compares the post-project condition with the pre-project (baseline) condition. Compensation activities that result in no measureable functional lift generate no credits, those that generate minimal functional lift, such as many enhancement activities, would generate minimal credits.

The CCMP indicates in Table 4.1.1 that “concurrent reclamation from ongoing mining activity” will accrue credits to be used as compensation to offset the mining disturbance. This is not possible. If the
post-mine reclamation is successful in fully restoring the aquatic resources to their pre-mine condition, there is still no functional lift relative to the baseline condition and therefore no mitigation credits are generated to use for compensation.

The establishment of additional aquatic resources relative to the existing condition would generate mitigation credits. The likelihood of successfully establishing an ecologically self-sustaining landscape with more streams and wetlands than currently exist appears slim, though climate models do predict increased precipitation in the future.

An additional problem with relying on the establishment of aquatic resources during site reclamation is that mitigation credits generally must be generated “prior to or concurrent with” authorized impacts. Mitigation credits are released after the achievement of performance measures identified in the mitigation work plan. This means that the success of the establishment must be shown before any credits could be allocated or released. If the phasing of the project were such that adequate time was available to demonstrate the success of establishment, those credits could be used to offset future impacts. Our understanding, however, is that the hydrology will not be re-established until the end of mine excavation.

Several decades of experience with compensatory mitigation and numerous studies have shown that success in generating functional lift is often elusive. The establishment, restoration, and enhancement of aquatic resources are risky endeavors. The Final Mitigation Rule requires the Corps to incorporate the consideration of risk into its compensatory mitigation decisions. This is generally done by applying ratios to required compensation so that the amount of compensation will be adequate to offset the authorized impacts even if the mitigation actions are not 100% successful.

The CCMP contains ratios from the Alaska District Regulatory Guidance Letter (RGL) 09-01. We understand the RGL has been withdrawn. Neither the RGL 09-01 nor the CCMP identifies a sample ratio for aquatic resource establishment, which is the riskiest form of compensation. Applying even a moderate ratio of 3:1 to establishment increases the compensation obligation substantially.

Take the case of the project’s stream impacts: Streams are defined by Corps and EPA regulations as “difficult to replace.” The Final Mitigation Rule indicates that such resources should be offset in-kind where possible. “In-kind” in general practice means not only stream-for-stream rather than wetland-for-stream, but also that functional gains and losses be matched by stream order or type where possible. This is because the functions performed by streams of different orders are distinct enough that functional gains to a third-order stream (e.g., coho habitat enhancement) cannot effectively offset functional losses to a first-order stream (e.g., nutrient cycling or flow moderation).

As discussed above, all of the direct stream impacts, not only the impacts to anadromous waters, must be compensated for. The Final Mitigation Rule indicates that preservation, restoration, and enhancement are all preferable to stream creation (establishment) due to the latter’s very high failure rate.
The Fish Protection Plan indicates that approximately 51.6 linear miles of jurisdictional streams will be impacted by the mining activity. The CCMP identifies different categories of stream and suggests different mitigation ratios. Using a preservation ratio of 2:1 simply for the sake of discussion means that over 100 linear miles of stream would need to be preserved to offset the impacts. Using a creation ratio of 3:1 means that over 150 linear miles of stream would need to be created. Again, for the compensation to be truly “in-kind” an analogous stream network, with first, second, and third order streams of similar physical characteristics would have to be preserved, restored, enhanced or established.

If the compensation were to be “out-of-kind” such as wetland enhancement to offset stream loss, then mitigation ratios would need to be higher. Suggested activities such as nutrient addition or the planting of hatchery stock may offset some of the lost fish production capacity, but actually do nothing to offset the loss of the aquatic resource itself. The streams and wetlands on the project site do much more than produce anadromous or even resident fish. If nutrient addition, for example, were considered as enhancement, credit generation would be minimal. If fish production is one of perhaps eight stream functions, then 400 linear miles of stream would need to be enhanced, even without applying a mitigation ratio.

The Fish Protection Plan proposes enhancing fish habitat in streams outside of the mine footprint by adding cover and bank complexity. Similar to nutrient addition, even if the enhancement were successful (and we are frankly skeptical), credit generation would be minimal. From this perspective, “Enhancing approximately 2 miles of stream channel [to] increase spawning and rearing potential” would fall about 398 miles shy of being adequate to offset impacts at a 1:1 ratio.

Section 5 of the Fish Protection Plan describes the design approach for stream and pond habitats. The text of this section is confusing, as it references stream channel restoration during mine-site reclamation and stream establishment prior to mining for compensation. The description of the existing conditions and the reference reaches is valid for post-mine reconstruction, but a mine-site reference reach cannot provide design information for a channel to be constructed at some other location.

As the Fish Protection Plan itself states, streams are a product of their environment. This is why most stream creation projects fail. Physically constructing a stream where the landscape does not currently support one does not alter that landscape. Reference data from some other landscape might as well be random. Unless you understand how water will move from the watershed to the constructed channel, you cannot predict the movement of that water through the channel, floodplain, and sediments. If you don’t have the basin hydrology, the sediment or wood supply to maintain a stream channel, construction efforts will be futile.
EPA Comments on the Revised Post-Mine Reclamation Plan Overview (dated August 2014) Conceptual Compensatory Mitigation Plan (CCMP) and Fish Protection Plan (both dated June 2014) for the proposed Chuitna Coal Project. October 2014.

Timing and Sequencing:

The mitigation sequence envisioned in the 404(b)(1) Guidelines, regulatory guidance, and the 1990 MOA between the EPA and Army Corps of Engineers (Corps) identifies compensatory mitigation as the third and final step in the mitigation sequence, with avoidance and minimization being the first and second steps, respectively. To date, it is EPA’s understanding that a LEDPA has not been identified and no formal 404(b)(1) Alternative Analysis has been completed. While deviations from the mitigation sequence (avoid, minimize, mitigate) are appropriate in certain circumstances, we do not believe that to be the case here. EPA appreciates the opportunity to review and comment on these conceptual mitigation and reclamation proposals, however, we believe a formal 404(b)(1) Alternative Analysis and finalization of the Alternatives section in the SEIS should be completed prior to proceeding with further detailed analysis and review of mitigation and reclamation proposals.

Impact Timing, Credit Generation and Release:

Regarding the timing of impacts, the Conceptual Compensatory Mitigation Proposal (CCMP) states that, “it is logical to measure the mine impacts on wetlands and streams as the mining advances....” This statement seems to imply the nature of surface mining results in only a portion of the mine site being impacted at any one time and, therefore, those impacts should be measured/calculated sequentially. The presumption is that some aquatic resources within the mine area will not be impacted until they are actually physically disturbed by the advancing mine strips. This is over simplistic and misleading. It is not simply the direct disturbance footprint that results in impacts to aquatic resources. While the final details of the mitigation plans and impact timing are not known, given the interconnected nature of this landscape and its aquatic resources, it seems likely that dewatering activities, blocked fish passage, and isolation and fragmentation of aquatic resources will all result in impacts to the aquatic resources and losses of function, including those outside any particular mine year disturbance footprint. While some aquatic resources may not be impacted or lose functions until later in the life of mine, we have not seen anything to support this conclusion. Once fish passage is blocked from Stream 2003 that function is lost for the entire upstream system. Once dewatering activities begin wetland impacts and losses of function will likely propagate outside of the direct mine footprint. Once surface water control features are installed and implemented certain wetland functions will begin to be lost.

Until appropriate data demonstrates that certain aquatic resources and functions will be retained until later in the life of mine, it seems prudent to assume that certain functions will begin to be lost over the entire system once preparation activities and mining commences. The impacts analysis section of the SEIS should clearly establish the timing/sequencing of impacts so the assumptions made in the mitigation documents can be verified or refuted.

In the CCMP it is stated that PacRim Coal (PRC) intends to pay wetland disturbance credits in advance of impacts as required by the 2008 Mitigation Rule, and that “it is logical...[to]...consider the reclamation that occurs as part of the mitigation for future mine advances.” Even without knowledge of the performance standards that will be used to determine the credit release schedule at the mine site, using ASCMCRA reclamation activities to generate and release compensatory mitigation credits to offset
impacts as the mine advances is not possible. Per the Mitigation Rule and 404(b)(1) Guidelines, mitigation activities and credit generation should occur in advance of, or concurrent with, project impacts. Credit means a unit of measure representing the accrual or attainment of aquatic functions at a compensatory mitigation site, and are generated after specific performance standards have been met and as outlined in an approved mitigation plan. Per the Mitigation Rule, credit release must be tied to performance-based milestones and the credit release schedule should reserve a share of the total credits for release only after full achievement of ecological performance standards. In addition, factors to be considered when determining the credit release schedule may include the likelihood of success and the nature and amount of work necessary to generate credits. As acknowledged in the Revised Post-Mine Reclamation Plan Overview (RP), it will take approximately 50 years from the beginning of mining activities for the hydrogeology of the mine area to become reestablished. While certain aquatic functions may begin to accrue as reclamation proceeds, and while the ecological performance standards for credit release have yet to be determined, it seems unlikely that full achievement of ecological performance standards will occur prior to the reestablishment of the system’s overall hydrogeology. Thus, generation and release of mitigation credits on the scale required to provide compensation for mining impacts will not be possible during reclamation activities occurring concurrent with mining. It seems likely that if any credits are generated by reclamation activities they would not be available for use until the pre-mining hydrogeology is restored. Without restoration of the hydrogeology of the system it is unclear how functional replacement and lift can occur at the mine site.

The performance standards and credit release schedule for the downstream enhancement activities outlined in the Fish Protection Plan (FPP) are also unknown at this time. If salmonid colonization or increased salmonid productivity are to be performance standards related to credit generation and release it seems likely that several years of monitoring will be required to demonstrate success and justify credit release.

EPA believes the credit release schedule should be developed in a conservative fashion given the amount of work necessary to generate sufficient credits to offset debits and the inherent and significant uncertainly of restoring full ecological function to the area post-mining. As outlined in detail by Kihslinger\(^1\), numerous studies have demonstrated that less than half of wetland mitigation sites meet their performance standards and can be considered ecologically successful and equivalent to replaced wetlands.

The timing of credit generation, and particularly credit release, is a significant issue that must be addressed to ensure that mitigation credits are generated concurrent with or in advance of project impacts.

Lastly, there remains significant uncertainty regarding the ability of the mitigation proposals to generate sufficient credits to offset the anticipated debits. Enhancement and preservation activities, as well as mitigation activities to offset temporal losses, typically require a higher mitigation ratio than other compensatory mitigation measures. Given the significant scale of aquatic resource impacts it remains unclear if enough credits can be generated from the enhancement, restoration, and preservation activities proposed to offset the anticipated debits to aquatic resources.

**ASCMCRA vs. 404:**

It remains unclear from the reports how the final reclamation plan will be coordinated with a final mitigation plan and, in particular, how the performance standards therein will be coordinated. The performance standards under ASCMCRA are typically related to the successful reclamation of the site to the approved post-mining land use, and are typically not related to ecologically meaningful metrics or restoration of aquatic resources and functions. The performance standards contained in an approved 404 mitigation plan deal entirely with ecological function. This discrepancy becomes important when considering the bonding provisions of ASCMCRA and how they will be coordinated with the financial assurance provisions of the 404(b)(1) Guidelines. If ASCMCRA bonding will be used as the financial assurance mechanism for 404 mitigation—as is stated in the CCMP—then biological criteria should be incorporated into the bond release performance standards and the typical bond release phasing schedule is likely not appropriate. Bond release under ASCMCRA typically occurs in three phases: Phase I bond release—which can be up to 60% of the total bond— involves successfully completing backfilling, regrading, and drainage control activities; Phase II bonds can be released when the site is successfully revegetated; Phase III bond release can occur after successfully completing all mining and reclamation activities and after a 10 year waiting period to demonstrate successful reclamation. The long-term monitoring and (anticipated) adaptive management of the mitigation sites (to ensure successful compensatory mitigation) is likely to take much longer than the backfilling, grading, and drainage control measures typically required for Phase I bond release. Given the uncertainty surrounding the ability to recreate functioning aquatic resources within the mine area, EPA believes additional biologically- and function-based performance standards should be incorporated into the bonding provisions and the amount of bond available for release at Phase I may need to be reduced. With the time scale required to restore the hydrology of the system (~50 years, as assumed by the RP) and ensure functioning aquatic resources are self-sustaining (~? years), it may not be appropriate to release 60% of the bond after completion of Phase I activities. The completion of Phase I activities (if limited to backfilling, grading, drainage control) in no way implies aquatic resource function is becoming reestablished or increasing.

**Compatibility of Post-Mining Land Uses:**

The post-mining land uses proposed by PRC can be generalized to include fish and wildlife habitat, functioning aquatic resources, and upland areas for future silviculture operations. Silviculture operations involve a variety of impacts including, but not limited to: increased erosion of soils, increased sedimentation of downstream surface waters, increased soil compaction and reduced groundwater infiltration/recharge and increased stormwater flows. Regulatory guidance\(^2\) encourages final mitigation plans to be compatible with adjacent land uses. At this time it is unknown if a long-term upland silviculture operation would be compatible with the self-sustaining and functioning aquatic resources planned in the riparian and lowland areas of the site. The details of the proposed silviculture operation should be discussed, including information on how the site(s) will be accessed, where support facilities will be located, whether timber processing will occur on site, and how the timber will be transported to

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market. These are all reasonably foreseeable future actions, indirect impacts of the proposed mine, and should be discussed in the SEIS as such.

Uncertainty

The reports do not adequately document the inherent and significant uncertainty in creating (or recreating) functioning aquatic systems and providing successful compensatory mitigation for impacts of this nature and scale. EPA is unaware of any examples where a pristine and functioning anadromous stream and wetland system was impacted and then successfully restored at the scale proposed. The examples included in the FPP are not readily comparable with the current proposal. Most examples are for side channel or stream reach construction/restoration, and are not nearly at the scale proposed by PRC. The largest stream reconstruction example involved 31,945 feet of stream; the total stream length (assuming only streams which are known to support fish are planned for reconstruction) identified in the FPP is over 150,000 feet, nearly five times the length of stream in the largest restoration example. The largest example of wetland construction involved 23.5 acres; the acreage of wetlands to be impacted by Chuitna is ~2,600, over 100 times the acreage of the largest example. In addition, it is our understanding that none of the examples provided involved reconstructing functioning aquatic resources in an area that was disturbed to the degree proposed by Chuitna (i.e., removing the salmon habitat, wetlands, hyporheic zone, and underlying geology, and altering the entire sub-basin’s hydrogeology through significant dewatering and surface water diversions).

The uncertainty of successfully restoring the mine site must be documented in the mitigation documents and SEIS, as well as the implications of unsuccessful restoration and mitigation failure. Examples of successful restoration or mitigation on the scale proposed should also be provided. If no comparable examples exist, that should be documented and acknowledged accordingly, as it has implications on the question of uncertainty.

Target Species

The FPP identifies restoring and maintaining coho habitat and productivity as the primary focus of fish habitat enhancement and mitigation activities. While coho salmon is the dominant species in the system (particularly in the upper reaches of the watershed), Chinook, pink, sockeye, and chum salmon are also important contributors to the Chuitna and upper Cook Inlet salmonid populations. Chinook salmon in particular are important from both an ecological perspective as well as an anthropogenic perspective (subsistence, commercial, sport fisheries, cultural). In addition, with the recent string of Chinook salmon fishery closures in Cook Inlet the past several years, maintaining the productivity of this species within the Chuitna watershed, which is recognized as being an important waterbody for Chinook in Cook Inlet, needs to be a goal of any proposed habitat enhancement or mitigation activities. Maintaining and restoring the biodiversity and species composition of salmonid species (and their pre-mine productivity) in the Chuitna system should be one of the goals of the mitigation proposals, and appropriate biodiversity and species composition performance standards should be included in the mitigation documents.

Issues Raised by ADFW Site Survey Report:
On July 15-17, 2014, Alaska State Biologists conducted a fish and site survey of the Chuitna mine area. A few issues were identified in the report which we believe are appropriate to raise in the context of our review of the Fish Protection Plan.

-The surveys documented anadromous fish populations in streams and lakes that were previously unsurveyed or contained limited or conflicting baseline information. The report concludes that up to 12 miles of stream habitat remains unsurveyed, with up to 10 miles being potential anadromous fish habitat.

-The report notes that an August 19, 2007, a survey of Lake 4 was conducted, during which the biologist may have improperly identified a coho salmon as a rainbow trout. This is serious cause for concern and raises the question of whether additional misidentification of salmonid species has occurred during previous baseline investigations.

The survey results and conclusions are a cause of concern and suggests that anadromous fish habitat may be underestimated in the project area. If confirmed, it is our understanding that this would nearly double the miles of anadromous stream currently documented. Additional monitoring/surveying is recommended to ensure all anadromous habitat is identified and cataloged within the mine area.
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Subject: Review of Rejection of Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260.

Executive Summary:
None of the examples provided by the Alaska Department of Natural Resources (ADNR) or PacRim demonstrate that reclamation is technologically feasible for streams and riparian corridors in the Chuitna watershed. The proposed project would remove 300 feet of overburden, mine the coal, then replace the overburden, in an attempt to build an entirely new stream and create a functioning stream ecosystem that supports anadromous salmon productivity similar to that which existed pre-mining. As none of the examples provided by ADNR or PacRim involved complete removal of an entire drainage with its associated salmon spawning stream, aquifers, wetlands, vegetation, and the subsequent creation of a new functioning stream on top of the mine overburden, no support is provided for the feasibility of reclamation of a coal strip mine in streams of the Chuitna watershed.

Not a common denominator
With the exception of Moose Creek, Resurrection Creek and Clear Creek in California, all of the streams Commissioner Sullivan cited as examples of successful reclamation of a salmon producing drainage and stream never supported anadromous salmon and are generally unsuitable as salmon habitat. The resident fish inhabiting streams cited by Commissioner Sullivan such as grayling, burbot, and round white fish have very different life histories and habitat requirements than Pacific salmon and cannot be used as surrogates in evaluating impacts or in determining the feasibility of the creation of salmon habitat. For example Arctic Grayling (Thymallus arcticus) migrate to headwaters streams and small tributaries such as Nome Creek and Valdez Creek in the spring to feed and spawn. Salmon dig redds into the hyporheic zone but spawning grayling do not. Grayling broadcast their eggs which drift down to the stream bottom where they develop. The eggs hatch within three weeks. It does not matter if these streams go anoxic, dry up or freeze to the bottom during the winter
because prior to freeze up both the adults and juveniles migrate out of these systems to deep rivers and lakes to overwinter (Alaska Department of Fish and Game [ADF&G], 2011). Furthermore grayling spawn annually so the loss of an entire year class does not have long-lasting consequences (U.S. Fish and Wildlife Service [USFWS], 1983).

In contrast, spawning Coho (*Oncoryhchus kisutch*), chum (*Oncoryhchus keta*), sockeye (*Oncoryhchus nerka*) and Chinook (*Oncoryhchus tshawytscha*) salmon (*Oncorynchus sp.*) select streams which flow year-round and have an adequate supply of ground water in the winter to support developing eggs and overwintering fry (USFWS, 2011). Pacific salmon select areas of ground water upwelling as redd sites (Geist, et al, 2001; USFWS 2011; and USFWS, 1983). Pacific salmon dig redds and deposit their eggs in the hyporheic zone of the stream bottom. The eggs develop over the winter months and the fry emerge the next spring. Depending on the species, fry may spend one or two years rearing in the same systems. If these streams dry up, freeze out, or go anoxic the eggs and fry will die. Pacific salmon die after spawning so the loss of a year class means that no salmon will return to that system in 2 to 4 years depending on the species

ADNR’s examples - Consol Energy’s Burning Star No. 4 and Amax’s Pipestone Creek - were coal mines but are not relevant to proposed Chuitna mining and reclamation. There are no anadromous salmon (*Onchorynchus sp.*) in the warm water streams affected by these mines. The primary fish species within the reclaimed Burning Star No. 4 mine area are largemouth bass (*Micropterus salmoides*), bluegills (*Lepomis marochirus*), and catfish (*Ictalurus* sp.) all warm water species. These species have very different life history and habitat requirements than anadromous salmon and salmon could not survive in the warm water lakes and streams these species inhabit. After the coal was depleted the Burning Star No. 4 mine was restored to cropland and water fowl habitat, not fish habitat. Similarly Amax’s Pipestone Creek restoration project only supports resident warm water fish.

The impacts of placer and gravel mining are very different than strip mining
ADNR’s Valdez Creek, Nome Creek, and Resurrection Creek examples of stream and wetlands reclamation post-mining were placer mines. Placer mining by definition is very different than the deep strip mining proposed for the Chuitna River drainage. Placer mining is defined as mining valuable minerals from placers by washing or dredging. A placer is a waterborne or glacial deposit of sand or gravel containing heavy ore minerals such as gold or platinum that has eroded from their original bedrock and can be washed (Webster’s New World Dictionary 1960). Placer mines do not mine through bedrock or continuous aquitards such as coal seams because the gold and platinum minerals are in the alluvium above the impervious layer. (See Diamond Shamrock 1990 FEIS at 4-25 to 4-27 (discussion of ground water hydrology impacted by proposed coal mining of coal seams located 300 feet below the surface). Because the placer minerals are found in stream channels or the alluvial flood plain, entire stream drainages and their watersheds are not usually mined as is currently proposed by PacRim in the Chuitna River drainage. Shallow aquifers outside of the placer mining area remain intact, although flow to stream channels may be detrimentally altered.
In-stream placer and gravel mining has been shown to be very destructive to fish habitat (including all of PacRim’s examples (Reynolds et al, 2007; Madison, 1981; and Weber, 1986). However, the damage to salmon streams from alluvial placer mining is very different from the much greater damage caused by surface coal strip mining which may encompass entire drainages and alter both the surface topography, subsurface geology, and numerous aquifers down to several hundred feet, (Starnes, L., and D.Gasper, 2011; Environmental Protection Agency [EPA], 1990; and National Oceanic and Atmospheric Administration [NOAA], 2007). Strip mining disrupts and/or destroys aquifers that recharge or replenish surface water systems which support salmon. Surface mining will necessarily cut through any aquifer above the coal seam that is being mined. Portions of aquifers and surface water systems may be dewatered. Disposal of water from mine pits will disrupt flow patterns, water temperatures and water quality in receiving waters (Starnes, L., and D.Gasper, 2011, EPA, 1990 and NOAA, 2007). It has yet to be demonstrated that a ground water system that has been destroyed by strip mining can be permanently restructured. Although there are examples of attempts to rehabilitate small sections of placer mined streams in Alaska, no examples were found where entire salmon stream drainages have been strip mined or placer mined and subsequently restored to previous levels of wild fish productivity. As the proposed Chuitna Coal Project would mine directly through a stream including its headwaters, alter the surface topography, subsurface geology, and numerous aquifers down to several hundred feet and replace the substrate with unconsolidated overburden, the reclamation of placer mined streams cannot be used as a surrogate or example of how reclamation from coal strip mining is technologically feasible. Placer mine reclamation in no way demonstrates or supports how reclamation of a coal strip mine as that proposed by PacRim is technologically feasible.

Lack of data

None of the citations for ADNR’s examples that I reviewed contained scientific studies that support ADNR’s contention that restoration of strip mined salmon habitat within the Chuitna River drainage is feasible. There is anecdotal information that stream restoration/reclamation has improved fish habitat and fish numbers from the damage caused by placer and gravel mining but no hard scientific data to support the claim that habitat and fish numbers have been returned to pre-mining numbers. In fact, a critical evaluation of in-stream restoration projects is often lacking or inadequate (Illinois Department of Natural Resources, 2010; Retzer, M.; and Carney, 2010). Nationwide less than 20% of all stream restoration projects are monitored after completion (Bernard et al, 2011). Even fewer stream reclamation projects are studied after completion to measure long term success or failure. For example, there is no scientific data to show that USFS reclamation projects on Resurrection Creek have restored salmon populations in the creek to pre-mining levels of productivity (Blanchet, 2011). In fact it is probable they have not (Blanchet, 2011). Similarly there are no pre- and post-project studies which show that the Cambior’s (Valdez Creek Mine) reconstruction of a one mile section of Valdez Creek cited by ADNR as an example of successful restoration, restored grayling populations in that portion of Valdez Creek to pre-mining levels.
Other agencies opinions on the technological feasibility of Chuitna watershed and salmon stream restoration

NOAA’s National Marine Fisheries Service (NMFS) is the nation’s expert on fisheries. The NMFS works to promote sustainable fisheries and to prevent lost economic potential associated with overfishing, declining species, and degraded habitats (NOAA, 2011). In a 2007 letter to EPA on the “the effects of the proposed Chuitna Coal Project on fish populations, habitat and water quality in the Chuitna watershed” the NMFS concluded that the Project would cause permanent impacts to the Chuitna Watershed and associated salmon habitat (NMFS, 2007). NMFS states that: “the applicants proposed stream restoration plan and supporting presentation highlights examples of stream restoration techniques widely recognized as the best available methods. However, the examples presented by the applicant represent restoration projects of far smaller scale stream realignments. These examples do not illustrate or represent stream restoration efforts at the size and scale of this mining operation where hydrogeomorphic processes are disrupted to a depth of 300 feet over several thousand acres. Stream restoration efforts at this scale would face many complications and impediments. We are aware of no example of successful salmon stream restoration at this scale” (NMFS, 2007). In the Diamond Chuitna Coal Project Final Environmental Impact Statement, EPA concluded it is questionable whether mined through streams could be returned to pre-mining productivity: therefore, fish productivity loss could be a long term loss (EPA, 1990).

The ADF&G also contradicted Commissioner Sullivan’s finding that creation of salmon producing drainages, watersheds, and associated aquifers is feasible in a May 26, 2011, letter to Russell Kirkham, ADNR Division of Mining and Water (ADF&G, 2011). This letter was in response to a letter from Russell Kirkham asking the ADF&G Habitat Division “does the information provided in the petition submitted by Trustees for Alaska, with additional information submitted by the interveners to the petition and the comments made by the general public or any other information known to the Department lead DF&G to believe that reclamation of anadromous waterbodies and riparian areas disturbed by surface coal mining operations is not technologically feasible under As 27.21 and 11 AAC90?” ADF&G provided the following response: “while we are aware of small scale successes in reclaiming certain stream functions we are not aware of any evidence documenting whether large-scale reclamation of ecosystem function can or cannot be accomplished.”

In the process of reviewing the projects that Commissioner Sullivan and PacRim cited as examples of stream restoration post-mining, a number of fisheries biologists and hydrologists who have been involved in stream reclamation projects in Alaska were interviewed (see references). None of the individuals involved in the projects cited in Commissioner Sullivan’s rejection of the Unsuitability Petition believed that these projects demonstrate that restoring thousands of acres of strip mined salmon streams, aquifers, and drainages was feasible. They were also unaware of any example of where a salmon producing drainage has been destroyed by strip mining to depths of several hundred feet, and a new stream created on top of several hundred feet of mine overburden.
Scale

All of the Alaskan projects cited by Commissioner Sullivan and Pac Rim as examples of the feasibility of restoring the Chuitna River drainage after strip mining are small-scale compared with the proposed Chuitna Coal Project. Both NMFS and ADF&G have pointed out the problems with attempting to use small scale stream realignment and reclamation projects as the basis for a conclusion that over 11 miles of salmon producing stream’s and drainage’s can be restored to pre-mining productivity when hydrogeomorphic processes have been disrupted to a depth of 300 feet over several thousand acres. The initial 5,000 acre mining area indentified in the 1990 EIS contains portions of tributaries 2002, 2003 and 2004. It is the first of three mine areas which have been proposed within the 20,571 acre coal lease area (EPA, 1990)). In contrast with the proposed Chuitna coal mine the Valdez Creek mine, which was the largest placer mine in Alaska, encompassed less than 640 acres.
Introduction

I reviewed the examples used by the Commissioner of the Alaska Department of Natural Resources (ADNR) in his Rejection of the Petition to Designate the Streambeds of Anadromous Water bodies and Riparian Areas within the Chuitna River Watershed as Unsuitable for Surface Coal Mining Pursuant to A.S. 27.21.260 (Petition Rejection) to support his claim that restoration activities at previously mined streams in Alaska and elsewhere demonstrate that it is technologically feasible to strip mine an entire drainage and its associated salmon streams to a depth of 300 feet for coal and then construct a fully functional watershed including salmon spawning and rearing streams on top of the formerly mined area (Sullivan 2011). I also reviewed examples relied upon by PacRim LC (PacRim), project proponent for the Chuitna Coal Project, to support their claims that past mining has been compatible with maintaining salmon production, and that restoration activities at previously mined streams in Alaska and elsewhere demonstrate that it is technologically feasible to strip mine an entire drainage and its associated salmon stream to a depth of 300 feet and then construct a fully functional watershed and salmon spawning and rearing stream on top of the overburden. To do this I perused the documentation in the citations provided by ADNR in its decision rejecting the petition, researched the available literature, and consulted biologists and hydrologists who were involved in these projects wherever possible. I also have first hand knowledge of many of the examples as a result of my experience during my 32 years as a fisheries research biologist and Habitat Division Regional Supervisor for the Alaska Department of Fish and Game (ADF&G).

I have previously described the likely impacts of the proposed Chuitna Coal Project on salmon habitat in the Chuitna River drainage based on the project analyzed in the 1987 Draft Environmental Impact Statement DEIS, the 1990 Environmental Impact Statement (EIS) for Diamond Alaska Coal Company’s application for a National Pollutant Discharge Elimination System (NPDES) permit and more recent PacRim studies, documents and permit applications (EPA, 1990). Based on my studies of the available information on similar strip mines and watershed reclamation projects worldwide since production of the 1990 EIS, I could not find any examples of anadromous streams and their associated watersheds and aquifers that had been restored to a productive state after strip mining. My findings are consistent with EPA’s conclusion that “it is questionable whether mined through streams could be returned to pre-mining productivity: therefore, fish productivity loss could be a long term loss, and NMFS’s comment to EPA on the scoping document for the Chuitna Coal project, “We are aware of no example of successful salmon stream restoration at this scale.“(EPA, 1990 and NMFS, 2007).

I explained why it was unlikely that stream affected by the proposed mine and the Chuitna watershed could be restored to their former level of productivity after strip mining in a report on PacRim’s Chuitna Coal Project Aquatic Studies and Fish and Wildlife Protection Plan (Trasky, 2010). I summarized these conclusions in a January 17, 2011, letter to Mr. Daniel S. Sullivan, Commissioner Alaska Department of Natural Resources, in support of the Petition to Designate the Streambeds of Anadromous Water Bodies and Riparian Areas within the Chuitna River Watershed, Alaska as Unsuitable for Surface Coal Mining Pursuant to AS. 27.21.260 (Trasky, 2011).
Review criteria:
I used two sets of related criteria to determine if the examples that Commissioner Sullivan used to support his rejection of the Unsuitability Petition provide scientific confirmation that restoration of Chuitna salmon streams is feasible after strip mining claims. The first is an evaluation of Commissioner Sullivan’s examples of mining and subsequent reclamation projects in compliance with the criteria in the Alaska Surface Coal Mine Control and Reclamation Act (ASCMCRA) regulations below:

1. Restore a strip mined watershed and associated anadromous stream to the uses which they were capable of supporting before any mining;

2. Avoid long-term adverse changes in the hydrological balance in the permit area and adjacent areas;

3. Minimize changes in water quality and quantity, in the depth and flow pattern of ground water, and in the location of surface and subsurface water drainages so salmon spawning and rearing are not adversely impacted;

4. Conducting strip mining for coal so as to restore the capacity of the area as a whole to transmit water to the ground water system supporting salmon spawning and rearing; or

5. Minimize disturbances and adverse impacts on fish, wildlife, and related environmental values and enhanced these values where practical; and,

6. Restore the recharge capacity to a condition that supports salmon spawning and rearing in reconstructed streams.

The second set of criteria used to evaluate if ADNR’s examples demonstrate the technological feasibility of reconstructing a fully functioning watershed, aquifers and salmon spawning and rearing stream on top of approximately 300 feet of replaced overburden are:

1. Was the stream salmon spawning and rearing habitat?
2. Were the entire stream, riparian area, and watershed mined?
3. Did mining penetrate bedrock or other impermeable layers and alter the shallow and deep aquifers that provide year round flow to the stream?
4. Were Pacific salmon, their habitat and the essential shallow aquifers supporting their freshwater lifecycle in the mined area restored or rehabilitated to their previous level of productivity after mining?
5. Were there any scientific studies of the mine or project to provide quantifiable data on the success of restoration?
6. What is the status of Pacific salmon populations after mining?
7. Was the project located in a cold climate where the input of ground water into the hyporheic zone and upwelling ground water into salmon spawning areas is essential to successful salmon spawning and rearing?

8. Were a fully functioning 11 mile long salmon spawning and rearing stream, and its associated watershed, aquifers, wetlands, and vegetation created on top of several hundred feet of replaced overburden in a former strip mine?

References


Analysis of ADNR Examples Used To Justify Rejection of the Unsuitability Petition

Following is an analysis of each example that Commissioner Sullivan cites to determine if they demonstrate the technological feasibility of reconstructing a fully functioning watershed, aquifers and salmon spawning and rearing stream on top of approximately 300 feet of replaced overburden and if they comply with the ASCMCRA regulations:

**ADNR Decision 138 Exhibit 2 Practical Examples of Fish and Wildlife Habitat Construction Reclamation and Restoration, PacRim Coal LP**

*Weaver Creek Spawning Channel*

The Weaver Creek Spawning Channel was constructed because flooding associated with extensive logging in the Weaver Creek drainage destroyed salmon spawning grounds in Weaver Creek (Fisheries and Oceans Canada, 2011). Sockeye escapement declined from an average of 20,000 sockeye salmon to 12,000 annually. To save this valuable run of salmon an artificial spawning channel was built beside Weaver Creek in 1965. This channel is a shallow stream with a gravel bottom and sloping sides built up with rocks, sockeye and a smaller numbers of chum and pink salmon deposit their eggs in this 2,932 meter (1.82 mile) long channel annually (Fisheries and Oceans Canada, 2011). An underground pipeline provides a dependable supply of water to the channel when eggs or fish are present. Water from Weaver Creek, Sakwi Creek, and Weaver Lake is piped to a large settling basin where it is treated to remove sediment. A second pipeline delivers clean water to the head of the spawning channel (Fisheries and Oceans Canada 2011). The run of sockeye produced by the Weaver Creek spawning channel is more than 200 times the size of the natural run produced from Weaver Creek prior to 1965. Because of construction and controlled water supply this spawning channel is really an outdoor salmon hatchery and is called that in some of the sources I reviewed. No mention of the rearing habitat for fry produced by this facility.

*Englishman River Spawning Channels*

The Englishman River originates on the slopes of Mt. Arrowsmith and flows 40 km before entering the Straits of Georgia near Parksville B.C. The river supports all five species of trout and salmon and is considered one of the most valuable but also endangered rivers in the province (Vancouver Island University, 2011). The Englishman River has experienced extensive channel widening and chronic sedimentation related to logging, reduced rearing habitat, and increasing sedimentation from increasing urbanization (B.C. Steelhead Recovery Plan, 2011). Sedimentation has reduced egg survival and ultimately salmon returns. Two semi-natural side channels (Weyerhaeuser channel and the Clay Young channel) have been constructed by the Division of Fisheries and Oceans (DFO) in an attempt to bolster declining runs of salmon and steelhead in the Englishman River. These channels accommodate a number of uses. Hatchery reared pink and Chinook salmon are stocked in the Clay Young channel. Pink salmon eggs are also placed in incubators in the Clay Young channel (Davies, 2011). Wild Coho, steelhead and other species of salmon also spawn in these channels. The two side channels produce between 15-25% of the Coho smolt produced in the drainage (Davies, 2011). The spawning channels do not seem to be too successful in reversing declining escapements.
Coho escapement into the Englishman River reached a high of 8,000 in 2001 but declined to 2,500 in 2009. Steelhead are present but apparently have declined to very low numbers. No information is available on the amount of available rearing habitat for Coho, Chinook, steel head and sockeye in this system.

The spawning channels on Weaver Creek and the Englishman River do not support the conclusion that reconstruction of a fully functioning watershed, aquifers and salmon spawning and rearing stream on top of approximately 300 feet of replaced overburden after strip mining in the Chuitna River drainage is technologically feasible. The Weaver Creek and the Englishman River drainages were damaged and their capacity to produce salmon greatly reduced by logging and other watershed developments. However, the impacts from these activities are relatively minor when compared to the disruption of surface and subsurface hydro geomorphic processes that would result from strip mining. The substitution of artificial spawning channels for natural habitat and wild stocks does appear to comply with the ASCMCRA regulations.

Although PacRim’s intent is not clear, it may be that they will propose to mitigate the loss of natural spawning and rearing habitat in the Chuitna River drainage by construction of artificial spawning channels. This solution is flawed for the following reasons:

1. Any Chinook, Coho, or sockeye salmon fry produced in a spawning channel would need rearing habitat. To replace natural stream habitat destroyed by strip mining up to 30 acres of high value rearing habitat would have to be replaced. Because of the presence of invasive northern pike in the Chuitna River drainage it could not be shallow ponds which have been shown to be good northern pike habitat (Rutz, 2011, Bosch, 2011, and USFWS, 1982). It would have to be relatively high gradient stream habitat similar to what which would be lost; otherwise the pike would simply eat all of the fry as they have in Red Shirt Lake, Cheney Lake, and many other systems in the Cook Inlet region. If the spawning channel were relatively low gradient such as the Weaver Creek spawning channel, it might also become prime northern pike feeding habitat.

2. A number of spawning channels have been constructed previously in Cook Inlet and all have failed over time because of flooding and other factors (Fandrei, 2011). The Weaver Creek spawning channel has likely succeeded because it is a very large, actively maintained facility, with a treated water source.

3. A number of spawning channels have been constructed in British Colombia to bolster declining fish runs related to habitat loss and degradation. According to the University of Washington, Weaver Creek is “one of the more successful ones” (Quinn, 2011). Some of these channels have failed and some have had limited success (Hartman and Miles, 1997). However, information is limited because agencies do not like to advertise their failures. Even if the problem of lack of Coho, Chinook, and sockeye rearing habitat and the presence of northern pike in the Chuitna River drainage are ignored, a spawning channel still may not be successful.
References:


ADNR Decision 163 and 164 Formerly Permitted Chuitna Project

In Decision 163, Commissioner Sullivan argues that the Unsuitability Petition fails to account for mitigation required by ADNR’s 1987 Permitting Decision, i.e. the creation of at least 4 one-half acre Coho salmon rearing ponds to be located adjacent to Coho salmon spawning habitat in tributary 2003. In Decision 164, he states that information regarding anadromous fish streams has advanced since the 1990 FEIS, as has the understanding of the technology used to restore fish productivity in disturbed areas. He points to the gravel pits at the Granite Creek material site as an example of the creation off channel rearing habitat.
It is true that the information on anadromous stream structure, function, and the relationship with surface and ground water flow and its watershed has advanced greatly since the 1990’s. The information on fish populations, genetics, and fish habitat in the Chuitna River drainage has also advanced. First, based on new information, 4 one half acre ponds are inadequate mitigation for the loss of approximately 30 acres of spawning and rearing habitat in the Stream 2003 watershed. It also would not compensate for the loss of spawning and rearing habitat for the other four species of salmon that are now known to use stream 2002, 2003 and 2004. Second, Granite Creek has not been disturbed by mining or any other activity. The 3 material sites which were used for local construction projects intercepted a shallow aquifer feeding Granite Creek and were flooded. The material sites were subsequently connected to the Granite Creek (Cross 2011 and Blanchet, 2011). It is correct that salmonids have been observed in these flooded material sites, but there is no information on numbers or if the material sites have increased the rearing capacity of Granite Creek (Cross, 2011). Unfortunately, similar attempts to increase spawning and rearing habitat by connecting flooded material sites to salmon streams have failed and some have become fish traps (Hughes, 2011; Ruffner, 2011; and Litchfield, 2011). The ADOT gravel pit on Quartz Creek and the gravel pits on the north fork of the Anchor River are examples (Hughes, 2011; Ruffner, 2011; and Litchfield, 2011).

Unfortunately, new information also shows that gravel pits and ponds also make good spawning and rearing habitat for northern pike (Rutz, 2011 and Bosh, 2011). Northern pike are not native to south central Alaska and threaten both wild and stocked fisheries (ADF&G, 2011). It is now known that northern pike have recently invaded the Chuitna River drainage (Rutz, 2011). No ponds, flooded gravel pits, or similar shallow low flow water bodies should be constructed in the Chuitna drainage because any juvenile salmonids utilizing them would be rapidly eaten by pike.

Commissioner Sullivan’s other mitigation examples such as artificial propagation (e.g., ARED) to enhance production without corresponding rearing habitat, and fertilizing with bone meal, transported salmon carcasses etc., do not appear to be consistent with the following ASCM regulations:

1. Restoring a strip mined watershed and associated anadromous stream to the uses which they were capable of supporting before any mining.

2. Avoiding long-term adverse changes in the hydrological balance in the permit area and adjacent areas.

3. Minimizing changes in water quality and quantity, in the depth and flow pattern of ground water, and in the location of surface and subsurface water drainage can so that salmon spawning and rearing are not adversely impacted.
4. Conducting strip mining for coal so as to restore the capacity of the area as a whole to transmit water to the ground water system supporting salmon spawning and rearing.

5. Minimizing disturbances and adverse impacts on fish, wildlife, and related environmental values and enhanced these values where practical.

6. Restoring the recharge capacity to a condition that supports salmon spawning and rearing in reconstructed streams.

References

Chilcote, M. 2011. USFS Fisheries Biologist Girdwood. 9/22/11 telephone conversation regarding Resurrection River reclamation, Granite Creek Gravel pits, Portage gravel pits and related subjects.

Cross, A., 2011. USFS Biologist. 9/22/11 telephone conversation regarding Granite Creek gravel pits, Cooper Creek; Daves Creek channel relocation and related subjects.

Bosch, D., 2011. Fisheries Biologist III, ADF&G Sport Fish Division 10/20/11. Telephone conversation regarding the use of gravel pits as habitat by northern pike.

Hughes, D., 2011. Fisheries Biologist III, ADF&G, Sport Fish Division. 10/18/11 Telephone conversation regarding failure of conversion of ADOT Quartz Creek Gravel Pit to salmon spawning and rearing habitat.

Litchfield, V, 2011. Habitat Biologist IV, ADF&G Habitat Division. Telephone conversation regarding failure of conversion of ADOT Quartz Creek Gravel Pit to salmon spawning and rearing habitat, other gravel pits, and Daves Creek.

Ruffner, R., 2011. Director, Kenai Watershed Forum. 10/18/11 telephone conversation regarding the conversion of gravel pits to salmon habitat.

Rutz, D., 2011. Retired ADF&G Fisheries Biologist/contractor on invasive species study. 10/19/11 Telephone conversation regarding northern pike distribution in west Cook Inlet and gravel pits as pike habitat.

ADNR Decision 176: Moose Creek:

The Moose Creek rehabilitation project does not demonstrate the technical feasibility of creating a new watershed, wetlands, shallow and deep aquifers, and a fully functioning salmon spawning and rearing stream on top of approximately 300 feet of coal mine overburden at the proposed Chuitna Coal Mine or anywhere else in the Chuitna
watershed where a stream is removed entirely and coal is mined 300 feet below that stream. Moose Creek was rerouted at several locations in the early 1900’s to facilitate the construction of a rail line to transport coal. Channel realignment resulted in significant loss of in stream aquatic habitat and floodplain connectivity as well as the formation of a ten foot high waterfall at mile 3 that blocked upstream salmon migration. Salmon populations that were once abundant enough to feed both miners and local people rapidly declined. However, remnant populations of Chinook, Coho and chum salmon continued to spawn and rear in the lower 3 miles of Moose Creek (Dryden et al, 2006; USFWS, 2011; Chickaloon Traditional Village Council 2011; and Winnestaffer, 2011).

Restoration of Moose Creek fish passage was championed by the Village of Chickaloon who traditionally harvested salmon from Moose Creek for subsistence. Restoration of salmon runs to upper Moose Creek was accomplished by:

1. Reconstructing two stream reaches to bypass several waterfall barriers.

2. Restoring channel connection to the adjacent floodplain-a connection which was lost when Moose Creek was straightened.

3. Revegetating the riparian habitat along the reconstructed reaches.

The project was completed in two phases: Phase 1 was completed in the summer of 2005. It involved restoring Moose Creek to a stable dimension, pattern, and profile adjacent to the upper waterfall at reach 3. After completion, both Chinook and Coho salmon were observed passing above the previously impassible barrier. Phase 2 was completed in the summer of 2006. It involved restoring Moose Creek to a stable dimension, pattern, and profile adjacent to the lower waterfalls at reach 5. In both reaches the channel realignment largely followed relic channel locations, although both the channel and floodplain were reconstructed throughout the new alignment (USFWS 2011).

Although several descriptions of the Moose Creek Fish Passage Restoration Project indicate that early underground mining, followed by adjoining strip mining operations severely altered more than seven miles of Moose Creek, it appears that most of the damage to Moose Creek addressed by this project actually occurred not from mining but from the rail line upgrade. When the rail line was upgraded to a standard gauge rail Moose Creek was rerouted, straightened, and channelized separating it from its flood plain, creating artificial waterfalls and impacting more than 7 miles of Creek (Sullivan, D. 2011; Winnestaffer, 2011; and USFWS, 2011). Although, underground coal mining along Moose Creek occurred and likely impacted the Creek in a number of ways, there is nothing in the record or literature which indicates that the bed and flood plain of Moose Creek were strip mined to any great depth, that the present stream substrate is old coal mine overburden, or that the aquifers providing the base flow to the creek were altered (Dryden, 2003). The fact that the channel realignment largely follows relic channel locations indicates that the stream and riparian area were not altered by mining but by dykes and levees built to confine Moose Creek to a single channel (USFWS, 2011).
project corrected a fish passage obstruction by returning a relatively short section (1850 feet) of the 7 miles of Moose Creek, which had been altered by the railroad, to its original channel in its original flood plain on top of an intact shallow aquifer. This project is completely different from reclamation necessary to create new salmon streams, aquifers, and drainages that would be destroyed by thousands of acres of coal strip mining in the Chuitina watershed. The Moose Creek restoration project fails to support in any way or demonstrate how reclamation and creation of entire salmon spawning and rearing stream’s with associated riparian areas, wetlands, and confined and unconfined aquifers on top of 300 feet of porous mine overburden is feasible.

References


Price, Mary 2011. USFWS Moose Creek Project Biologist. Personal communication regarding Moose Creek stream restoration and coal mining, October 25, 2011.


Winnestaffer, Brian, 2011. Fisheries Biologist Chickaloon Village Traditional Tribal Council: Personal communication regarding Moose Creek stream restoration and coal mining, October 25, 2011.
ADNR Decision Nome Creek

Nome Creek is a grayling stream and portions of the creek and its riparian area were extensively placer mined for gold from the turn of the century to recent times (Kostohrys, J. 2007). Miners disturbed over 7 miles of the 22 mile long stream, often by diverting it into bypass channels or through old settling ponds. By the 1980’s the floodplain was largely obliterated in many areas (Kostohrys, J. 2007). The Bureau of Land Management’s (BLM) reclamation objectives for Nome Creek were:

1. Keep Nome Creek within a single channel.

2. Eliminate unstable debris piles and settling ponds that have contributed to excessive sediment runoff.

3. Stabilize and revegetate the flood plain. BLM plans to apply the techniques that were successful at Nome Creek to other placer mining reclamation (Kostohrys, J. 2007).

Commissioner Sullivan cites BLM’s efforts to stabilize and revegetate heavily placer mined sections of the Nome Creek channel and adjacent riparian area and reestablish Nome Creek in a single channel as an example of the technical feasibility of restoring salmon streams in the Chuitna River drainage after strip mining for coal. Nome Creek may be a good example of the techniques used to reclaim a placer mined grayling stream, but it does not demonstrate the technical feasibility of:

1. Creating a entirely new watershed where the Middle Creek watershed currently exists after the majority of the watershed is strip mined to a depth of 300 feet (NMFS, 2007)

2. Maintaining slope stability and water quality while the watershed is being revegetated over many years

3. Successfully revegetating the watershed and riparian areas with plant species that provide organic material and nitrogen that have been shown to be essential to productive salmon rearing streams (Wipfl, M., J. Richardson, and R. Naiman. 2007, and King et al .in review)

4. Reconstructing shallow and deep aquifers to provide phreatic and hyporheic ground water flow to a newly created stream to replace Middle Creek and other streams which may be obliterated by strip mining (Winter et al, 1998; Stanford, J., .and J. Ward, 1993; and Reidy and Clinton, 2004)

5. Constructing a stable and fully functioning salmon spawning and rearing stream with the same water quality and chemical homing signature as the mined stream on top of 300 feet of coal mine overburden.
6. Maintaining the genetically unique stocks of 6 species Pacific salmon currently inhabiting Middle Creek and other similarly affected stream for 25 years before a new stream is created.

Nome Creek reclamation does not support Commissioner Sullivan’s finding that it would be technically feasible to restore streams destroyed by coal strip mining, such as that proposed by PacRim to their previous levels of productivity, for the following reasons:

1. Nome Creek was not strip mined, it was placer mined down to bedrock (17-20 feet).

2. The watershed was not mined, only 7 miles of the 22 mile long stream channel and adjacent riparian area.

3. The aquifers providing base flow to Nome Creek were not altered (Kennedy, 2011 and Kostohrys, J., 2007).

4. Nome Creek is a grayling stream and no Pacific salmon are present. Sections of Nome Creek freeze to the bottom which would eliminate salmon spawning or overwintering. Grayling survive in Nome Creek because they leave Nome Creek when it begins to freeze up in the fall and overwinter in lakes and large rivers (Fleming and McSweeny, 2001; Kennedy, B., 2011; and Kostohrys, J. 2007).

5. Reclamation at Nome Creek consists of grading placer mined gravels to create a stable channel and fertilizing the riparian area to encourage growth of pioneering plant species.

In contrast, reclamation at the proposed Chuitna coal mine would require creation of an entire watershed, with associated aquifers, wetlands, and a fully functioning salmon stream on top of 300 feet of mine overburden (Kennedy, B., 2011; Kostohrys, J., 2007; and Kostohrys and Koss, 2011). Nome Creek is likely better habitat for grayling as a result of the BLM reclamation efforts. However, as with most reclamation projects in Alaska, no pre- and post-project scientific studies with data confirming that grayling densities have improved as a result of the reclamation efforts could be found (AECOM Environment, 2009). Even if grayling numbers improved, it does not establish the feasibility of reclamation following strip coal mining to 300 feet in the portions of the Chuitna watershed covered by the unsuitable lands petition.

References:


ADNR Decision 174. Valdez Creek

Cambior’s (Valdez Creek Mining Company) reclamation of the 600 acre Valdez Mine and the construction of a one mile section of new stream channel at the Valdez Creek Placer mine are cited by Commissioner Sullivan an examples of mining-related successful stream reclamation. Cambior reclaimed the placer mine site by infilling, landscaping, and reseeding the waste dump, flooding the open mine pit to create a lake more than a half mile wide, and by recontouring and rebuilding the creek bed to follow its original course (King, 1997). The restoration plan also called for the rehabilitated channel of Valdez Creek to conform as closely as possible to the grade and curve of its original course. The newly reconstructed stream bed was lined with rocks and boulders, liberally placed to moderate the flow velocities and provide a habitat for migrating fish species such as grayling and whitefish. In total, more than 5,200 feet of Valdez Creek was rebuilt (King, 1997). Most of the roads used during the mining project have been reseeded. However, an unpaved access road from the Denali Highway provides access to the site and several mining claims further upstream.

As stated previously, because of the type of mining at this site (placer) and the absence of any of the five species of Pacific salmon in Valdez Creek, reclamation at this site does not demonstrate that successful reclamation of thousands of acres of watershed and more than 11 miles of salmon spawning and rearing streams in the Chulitna River drainage after strip mining is feasible. The scale of mining at Valdez Creek was small (600 acres) compared with proposals to strip mine over 5,000 acres containing three salmon streams within the 20,571 acre coal lease area in the Chuitna River drainage. Mining was also limited to Valdez Creek, its riparian area, and old channels and not the entire watershed.

Because there were no scientific studies of fish populations, fish habitat, and hydrology in Valdez Creek before mining and apparently no post project studies in the reconstructed portion of Valdez Creek, there is no data to support ADNR’s claim that stream reconstruction was successful in providing productive habitat and access to upstream habitat (BLM, 1986; Sundlove 2011; and Whitlock, 2011). The lack of long term monitoring and critical evaluation of stream restoration projects is a common problem nationwide (Nawrot et al, 1999 and Bernhardt et al, 2011). One cause for skepticism about the long term success of this reclamation project is that ADF&G biologists recently studied the fish passage structures at Valdez Creek road crossings and found that all the culverts were crushed and blocked with debris. None of the culverts met USFS fish passage criteria (O’Doherty, 2011). This means that passage from overwintering areas into the Valdez Creek mining area may be blocked, particularly for juvenile fish. It also illustrates that reclamation projects may appear to be successful initially, but fail over time if there is no maintenance after completion. It is important to note that BLM monitoring of stream reclamation and stream stabilization projects in Nome Creek reported that high waters damaged reconstructed channels and riparian areas (Kostohrys, 2007). Similar high water events in Valdez Creek may have caused changes in the Valdez Creek channel, but since there have been no post project studies there is no way to tell if the reclaimed channel is still intact. Several of the current and retired agency personnel interviewed about the Valdez Creek Mine described the mining area as “a mess.”
The Cambior reclamation at Valdez Creek cannot be used to demonstrate the feasibility of restoration of a watershed, numerous shallow and deep aquifers, and a Pacific salmon spawning and rearing stream. As previously described, Valdez Creek is a grayling stream. Grayling and anadromous salmon have very different life histories and grayling can survive where Pacific salmon cannot. As long as Valdez Creek has adequate surface flow in the summer grayling can survive in the Valdez Creek system if the one mile restored section has adequate summer flow to allow grayling to reach upstream areas, and the Cambior culverts in Valdez Creek and its tributaries are not blocking fish passage. Winter conditions in the Creek aren’t important because adult and newly hatched juvenile grayling leave streams such as Valdez Creek before they freeze to the bottom and migrate to deep rivers and lakes to overwinter. The eggs and larvae of anadromous salmonids found in the Chuitna drainage must remain in spawning and rearing systems overwinter, and if the stream freezes to the bottom, dries up, or goes anoxic, they die.

On page 83 of Commissioner Sullivan’s petition rejection it states that “While there are no anadromous fish that are supported in the river sic, it is an important example of stream reclamation after substantial disturbance to the hydrological balance by a relatively deep surface mining operation. The post-mining stream on this site was constructed on reclaimed mine spoils that were replaced in the same general configuration as the pre-mining stratigraphy, including substantial thicknesses of glacial fluvial material overlying Tertiary fluvial deposits and deeply incised paleochannels.” No post project scientific studies or scientific reports on fish populations, fish habitat, or hydrology could be located to support Commissioner Sullivan’s claim that the Valdez Creek Mine is an example of mining-related successful stream reclamation from a fisheries and hydrological perspective, and that the stream channel and hydrological balance were restored when the post mining stream “was constructed on reclaimed mine spoils that were replaced in the same general configuration as the pre-mining stratigraphy, including substantial thicknesses of glacial fluvial material overlying tertiary fluvial deposits and deeply incised paleochannels.” Commissioner Sullivan’s statement creates the impression that the hydrology of Valdez Creek was disrupted by placer mining and then restored by replacing “reclaimed mine spoils in the in the same general configuration as the pre-mining stratigraphy.” However, there is nothing in Commissioner Sullivan’s Valdez Creek references or the record that supports the claim that the hydrology of Valdez Creek was disrupted and then restored. The Bundtzen and Reger (1990) citation provided by Commissioner Sullivan to support this claim is only a description of glaciations and gold-placer formation in the Clearwater Mountains and does not discuss how Cambior replaced mine spoils to restore the pre-mining stratigraphy or the hydrological balance. The Bundtzen and Reger report was apparently written before the Valdez Creek channel reconstruction occurred (Bundtzen and Reger, 1990). ADNR’s publication on Mining Reclamation in Alaska which was also cited does not provide any information on hydro-geological reclamation techniques used at mines (ADNR, 1997). There is no evidence in the record that supports the statement that the pre-mining stratigraphy and hydrology were restored.
References:


McKay, D. 2011. Telephone conversation with Don McKay ADF&G Habitat Division Region 2 Permitting Supervisor (retired) regarding Valdez Creek Mine permitting, restoration and current condition.

O'Doherty, 2011. Alaska Department of Fish and Game, Habitat Biologist III: Telephone conversation regarding fish passage at Valdez Creek Mine 9/27/11.


Sundlove, Tim, 2011. BLM Fisheries Biologist Glenn Allen: Telephone conversation regarding fish species, mining, reclamation and present condition of Valdez Creek Mine 9/27/11.


ADNR Decision 177 Resurrection Creek

The United States Forest Service (U.S. Forest Service) reclamation of Resurrection Creek and its riparian area does not demonstrate the technological feasibility of restoring the Chuitna drainage after strip mining because the type and extent of mining was very different. Resurrection Creek is approximately 25 miles long. All five species of Pacific salmon are found in Resurrection Creek. Salmon spawning and rearing has been documented from tide water to river mile 18. Placer mining operations altered the stream channel and the riparian area of Resurrection Creek from approximately river mile 2 to river mile 6.5 (U.S. Forest Service, 2002). Although, little pre-mining information is available it is likely that Resurrection Creek was a productive salmon spawning and rearing stream and the heavily mined section may have contained the best spawning and rearing habitat (Blanchet, 2011). The portions of Resurrection Creek above and below the mined area were largely undisturbed. In the heavily mined area placer miners straightened and lowered the Creek, destroyed the riparian area, and washed the organic material into the Creek (Blanchet, 2011; U.S. Forest Service, 2002; and Wild Fish Initiative, 2006). The Resurrection Creek stocks of spawning salmon had access to all areas of the Creek even during mining. The watershed wasn’t mined; only 4.5 miles of the Creek bed and portions of the flood plain. Because placer mining did not penetrate bedrock/aquitards underlying the Creek the aquifers providing phreatic and hyporheic flow to Resurrection Creek and its tributaries did not require restoration (McFarland, 2011; U.S. Forest Service, 2002; and U.S. Forest Service, 2007).

The U.S. Forest Service projects to restore channel stability, create off-channel rearing habitat, level tailings piles, introduce large woody debris, and revegetate riparian areas in the 4.5 miles of Resurrection Creek that was altered by placer mining do not demonstrate the technological feasibility of restoring the Chuitna watershed and its salmon spawning and rearing streams to pre-mining levels of productivity. The USFS did not need to construct a new watershed, revegetate the watershed, construct new aquifers, and create new wetlands. Only a relatively small portion of the Resurrection Creek bed and riparian area were mined, compared to the 20,571 acre Chuitna coal lease area and the 5000 acres of the watershed proposed to be strip mined and then restored by PacRim (NMFS, 2007). Because the Resurrection River was never blocked all genetically distinct salmon stocks in Resurrection Creek are likely still present albeit in smaller numbers. This is much different from the PacRim Chuitna mining proposal where access to spawning and rearing areas would be blocked for decades. The USFS did not have to build a stable fully functioning stream on top of 300 feet of mine overburden as would be required if strip mining is permitted in the Chuitna River drainage. Comparing the difficulty of the work necessary to reclaim the 4.5 mile section of Resurrection Creek that was placer mined with the difficulty of reconstructing strip mined watersheds in the Chuitna drainage is akin to comparing the work required to restore a car after a severe accident with that required to building a new car from raw steel and rubber.

U.S. Forest Service reclamation to improve fish habitat in Resurrection Creek is laudable but does not demonstrate that reclamation of streams in the Chuitna watershed and
compliance with the following Alaska Surface Coal Mining Regulations is technologically feasible for the following reasons:

1. **Restoring a strip mined watershed and associated anadromous waters to the uses which they were capable of supporting before any mining:** The Resurrection Creek watershed wasn’t strip mined. A 4.5 mile section of Resurrection Creek and its flood plain were placer mined which, although very destructive, is a much lower level of disturbance than strip mining which would remove all features in the Chuitna watershed down to a depth of 300 feet below present stream level. The U.S. Forest Service has improved spawning and rearing fish habitat in the 4.5 miles of Resurrection but probably not to pre-mining levels (Blanchet, 2011).

2. **Avoiding long-term adverse changes in the hydrological balance in the permit area and adjacent area’s:** Placer mining caused long term adverse changes in surface flow by lowering and straightening Resurrection Creek. However, because placer mining was limited to a very small portion of the watershed, and did not penetrate bedrock below the flood plain, ground water flow to the Creek was not altered (Blanchet, 2011 and McFarland, 2011). No aquifers were destroyed or reconstructed in the Resurrection Creek drainage.

3. **Minimizing changes in water quality and quantity, in the depth and flow pattern of ground water, and in the location of surface and subsurface water drainage can so that salmon spawning and rearing are not adversely impacted:** For reasons previously discussed placer mining in Resurrection Creek seriously impaired water quality and altered surface flow but apparently did not alter ground water depth and flow patterns (McFarland, 2011). The U.S. Forest Service has attempted to improve salmon spawning and rearing in the mined area in a 4.5 mile section of Resurrection Creek by stabilizing the channel, creating off channel rearing habitat, revegetating the flood plain and placing large woody debris in the channel for cover. Because the watersheds, existing salmon streams, and the existing shallow and deep aquifers in the Chuitna drainage would be completely destroyed by strip mining, changes in water quantity, the depth and flow patterns, of ground water, and the location and the location of surface and ground water would not be minimized and current salmon spawning and rearing areas would be destroyed.

4. **Conducting strip mining for coal so as to restore the capacity of the area as a whole to transmit water to the ground water system supporting salmon spawning and rearing:** there was no strip mining in the Resurrection Creek drainage, and as a result no need to attempt to restore aquifers throughout the drainage which would be disrupted by strip mining.

5. **Minimize disturbances and adverse impacts on fish, wildlife, and related environmental values and enhanced these values where practical:** placer mining in Resurrection Creek did not minimize disturbances or adverse impacts.
6. **Restore the recharge capacity to a condition that supports salmon spawning and rearing in reconstructed streams.** Resurrection Creek was not strip mined so the U.S. Forest Service did not have to attempt to restore the recharge capacity.

**References:**


ADNR Decision 178: Clear Creek

Historically, lower Clear Creek in California supported populations of fall-run, late fall-run and, to a lesser extent, spring-run Chinook salmon (*Oncorhyncus tshawytscha*) and steelhead (*Orcorhynuchus mykiss*). The latter two populations are presently extirpated from the stream. The cumulative effects of placer mining, gravel extraction, dams, timber harvest, developments, and roads in the lower Clear Creek watershed have led to degradation of stream channel and riparian conditions and the decline of the lower Clear Creek fishery (Wildfish Habitat Initiative, 2011).

Restoration included returning Clear Creek to a more natural meandering course and pits and ponds that once stranded out migrating juvenile salmon were eliminated. A dam was removed. Some riparian areas were replanted. Floodplains were repaired to allow the stream to respond to, and recover from high water flows (U.S. Bureau of Land Management [BLM], 2006). Gravel needs to be added to Clear Creek in perpetuity to replace alluvial material which has been lost because of gravel mining and dams (Wildfish Habitat Initiative, 2011).

The impacts to Clear Creek and the reclamation projects described in the literature have little relevance to the magnitude of watershed disruption and reclamation challenges presented by strip mining anadromous streams and their drainages in the Chuitna River drainage. Clear Creek and its drainage was not strip mined so the aquifers feeding the Creek were not detached from the Creek (Wildfish Habitat Initiative, 2011 and NSR/McBain&Trush/Matthews&Associates, 2000). One of the biggest impacts to salmon spawning was the construction of two dams and gravel mining in the flood plain which robbed Clear Creek of aggregate needed to replenish spawning gravels (Wildfish Habitat Initiative, 2011). Because of the dams and depletion of flood plain gravel, gravel will need to be added to Clear Creek in perpetuity. Gravel is purchased and dumped into Clear Creek annually to replace spawning gravel that is washed downstream (Brown, M. and J. De Staso, 2005).

The climate in the Clear Creek drainage is Mediterranean, subsequently there is no danger of salmon redds and rearing salmon fry freezing out in the winter. In contrast the Chuitna River drainage has a very cold climate. There are 5 months of below freezing weather in the winter where stream flow and juvenile salmon and egg survival is solely dependent on the uninterrupted flow of ground water.

Although reclamation has improved fish habitat in Clear Creek California, it does not demonstrate that compliance with the following Alaska Surface Coal Mining Regulations is technologically feasible for the following reasons:

1. *Restore a strip mined watershed and associated anadromous waters to the uses which they were capable of supporting before any mining:* The Clear Creek watershed was not strip mined. The BLM did not have to attempt to reconstruct an entire drainage and a functioning salmon stream on top of 300 feet of mine overburden. One of the biggest impacts to salmon spawning was the construction
of two dams and gravel mining in the flood plain which robbed Clear Creek of flood flows and gravels needed to replenish spawning beds (Wildfish Habitat Initiative, 2011). Because of the dams and depletion of flood plain gravel, gravel will have to be added to Clear Creek in perpetuity. Clear Creek is not really restored because gravel has to be purchased and dumped into Clear Creek annually to replace spawning gravel that is washed downstream (Brown, M, and J. De Staso, 2005). This system is being maintained artificially.

2. **Avoiding long-term adverse changes in the hydrological balance in the permit area and adjacent area’s:** Long term adverse changes were not avoided because the construction of dams and gravel mining robbed Clear Creek of the natural flow of essential spawning gravel. Gravel mining is very different than strip mining because it only removes the alluvium above underlying aquitards and does not penetrate or disrupt them. However, because gravel mining did not penetrate bedrock and the hardpan below the flood plain, ground water flow to Clear Creek was not curtailed (NSR/McBain&Trush/Matthews&Associates, 2000). No aquifers were reconstructed during reclamation.

3. **Minimizing changes in water quality and quantity, in the depth and flow pattern of ground water, and in the location of surface and subsurface water drainage can so that salmon spawning and rearing are not adversely impacted:** For reasons previously discussed, gravel mining and dam construction in Clear Creek seriously depleted stream gravel, and made stream channels wider and shallower but did not alter ground water quantity, depth and flow patterns. The BLM has attempted to improve salmon spawning and rearing in the mined area in Clear Creek by restoring the stream channel, revegetating portions of the flood plain and placing root wads to retard stream bank erosion and provide cover for juvenile salmon.

4. **Conducting strip mining for coal so as to restore the capacity of the area as a whole to transmit water to the ground water system supporting salmon spawning and rearing:** there was no strip mining for in the Clear Creek drainage, and as a result no need to attempt to restore ground water discharge disrupted by strip mining.

5. **Minimize disturbances and adverse impacts on fish, wildlife, and related environmental values and enhanced these values where practical:** placer mining, gravel extraction, dams, timber harvest, developments, and roads in the lower Clear Creek watershed were not conducted in a manner which minimized disturbances and adverse impacts to fish, wildlife, and enhanced those values

6. **Restore the recharge capacity to a condition that supports salmon spawning and rearing in reconstructed streams.** Clear Creek was not strip mined so the BLM did not have to attempt to restore the recharge capacity of the Clear Creek drainage.
References:


ADNR Decision 179 Silver Bow Creek Butte Montana

Cleanup and remediation of toxic mine waste in the Silver Bow Creek drainage does not demonstrate the technical feasibility of strip mining a drainage and recreating a watershed, shallow and deep aquifers, and a productive salmon spawning and rearing stream on top of 300 feet of mine overburden. Silver Bow Creek and its drainage was not strip mined. Silver Bow Creek was used as a conduit for mining, smelting, industrial, and municipal waste for more than a hundred years (EPA, 2011). Resident fish, other aquatic life, and riparian vegetation originally found in and along the Creek were killed by acid mine drainage and heavy metals leaching from vast piles of mine tailings piles dumped in and along Silver Bow Creek (EPA, 2011, and Montana Department of Environmental Quality [DEQ], 2009). Both surface and ground waters were contaminated with toxic levels of copper, zinc, cadmium and lead. Municipal sewage from Butte Montana also contributed to the pollution of Silver Bow Creek. EPA declared the area as a superfund site in 1983 and subsequently obtained a $215 million dollar settlement from ARCO.

Remediation of Silver Bow Creek included removal of 4.5 million cubic yards of contaminated mine tailings from the creek bed and riparian area. Clean fill material was brought in to construct a 200-400 foot wide flood plain and a low flow meandering stream channel (TT Strategic Media, 2011). The flood plain and stream banks were revegetated. In 2008 electro fishing at six locations captured hundreds of suckers and four trout (Montana DEQ, 2008).

The Silver Bow reclamation project has little relevance to the reconstruction challenges presented by proposed strip mining in the Chuitna drainage. Silver Bow Creek was not strip mined, it was poisoned by heavy metals and acid mine drainage. There never were any anadromous salmon (Onchoryncus sp.) in Silver Bow Creek. The life history and habitat requirements of the freshwater suckers and trout currently inhabiting Silver Bow Creek are very different than anadromous salmon (Raleigh, et al, 1984 and Edwards., 1983). The Creek’s aquifers and ground water supply were contaminated, but not destroyed. The aquifers did not have to be constructed. Remediation undoubtedly improved Silver Bow Creek which was devoid of aquatic life, but it has not been restored to its pre-mining condition. According to Joel Chavez, Montana DEQ project manager, “it is not a thriving fishery or a blue ribbon trout stream but it’s evident that the work we have been doing is helping” (Montana DEQ, 2008).

Given the extensive differences in the Silver Bow restoration project compared to the type of reclamation necessary to reclaim streams mined in the Chuitna watershed, the Silver Bow restoration project fails to provide any support that reclaiming streams and restoring pre-mining fish productivity in the Chuitna watershed from coal strip mining is technologically feasible.
References:


Cousins, S. 2000. Bioengineered Streambank Stabilization on Silver Bow Creek. Website: http://ecorestoration.montana.edu/mineland/histories/superfund/silver_bow/default.htm


ADNR Decision 180: Consol Energy’s Burning Star 4 Mine, and Pipestone Creek Reclamation

Other than the fact that both Consol Energy’s Burning Star No. 4 mine, and AMAX’s Pipestone Creek were former strip coal mines there is no similarity between the reclamation at these mine sites and the reclamation challenges presented by PacRim’s proposal to strip mine coal on 5000 acres of the Chuitna River drainage. The Burning Star No. 4 mine and Pipestone projects are located in southern Illinois. According to the Consol website approximately 3,200 acres of land that previously contained wetlands and prime farmland were reclaimed. The highlight of this project was the restoration of more than 148 acres into wetlands, and the reestablishment of 1,400 acres of cropland (Consol Energy, 2011). For the first time in Illinois two major streams in a minefield were diverted during mining and then restored to their original locations and reclaimed as a habitat for wildlife and waterfowl. (Consol Energy, 2011 and Nawrot et al, 2010 and Illinois Department of Natural Resources, 2010). The primary fish species within the reclaimed mine area are largemouth bass (Micropterus salmoides), bluegills (Lepomis marochirus), and catfish (Ictalurus sp.) - all warm water species.

Restoration on the AMAX Pipestone project in began in the 1980’s and continued to the 1990’s. The Pipestone mine was reclaimed to wetlands, ponds, lakes and farmland. According to a monitoring report the reclaimed section of Pipestone Creek is a low gradient turbid warm water stream which according to post-restoration reports supports brook silverside and blackstripe top minnow (Illinois Department of Natural Resources, 2010).

Reclamation at the Burning Star 4 and Amax Pipestone mines does not support Commissioner Sullivan’s finding that it is technologically feasible to restore salmon producing steams, and their associated drainages and aquifers in the Chuitna watershed to pre-mining level of productivity after strip mining. Reclamation at these mines also does not demonstrate compliance with the following Alaska Surface Coal Mining regulations:

1. Restoring a strip mined watershed and associated anadromous stream to the uses which they were capable of supporting before any mining. There are no salmon in the warm water streams in the Burning Star No. 4 and Amax Pipestone mine areas. The literature for Burning Star No. 4 indicates that the primary species in the former mine area are largemouth bass, bluegills, and channel catfish. Only brook silverside and blackstripe top minnow, which are warm water fish were identified in the monitoring report for the Pipestone Project. These species could not survive or reproduce in the Chuitna River drainage. Similarly salmon could not survive or reproduce in southern Illinois streams because the habitat and water quality is not suitable. The mined lands were restored to farmland, and wildlife and water fowl habitat, not salmon spawning and rearing habitat. The land in Illinois is generally flat with well developed soils, unlike Chuitna which is mountainous with poorly developed soils. The climate at Chuitna is also much colder and the winters are much longer. There are three months (December-February) with below freezing weather conditions in Illinois. Average monthly lows range from 29 degrees (Fahrenheit) in December to 28 degrees
(Fahrenheit) in February. The Chuitna drainage has over 5 months of below freezing weather. Temperatures range from an average of 16.5 degrees (Fahrenheit) in December to 25.5 degrees (Fahrenheit) in March. Long months of below freezing temperatures eliminate surface flow. Long cold winter makes it critical that the flow of phreatic ground water to streams supporting developing salmon eggs and larvae is maintained, whereas this is not an issue in Illinois or Indiana.

2. Avoiding long-term adverse changes in the hydrological balance in the permit area and adjacent area’s; The literature on these mines that I was able to find did not indicate that the hydrological balance in restored stream had been restored, but that they were in a “long-term geomorphological and biotic recovery process.” (Nawrot et al, 2010).

3. Minimizing changes in water quality and quantity, in the depth and flow pattern of ground water, and in the location of surface and subsurface water drainage can so that salmon spawning and rearing are not adversely impacted. There are not now and never were salmon spawning and rearing in the streams in the mining areas. The climate, streams, substrate, water temperatures etc are all unsuitable for salmon.

4. Conducting strip mining for coal so as to restore the capacity of the area as a whole to transmit water to the ground water system supporting salmon spawning and rearing; No information was provided as to how or if the capacity of the area to transmit water to the ground water system was restored. However, because the life history and habitat requirements of the fish species found in southern Illinois are completely different (i.e. they do not depend on upwelling ground water for spawning or overwintering) it may not have been an issue.

5. Minimizing disturbances and adverse impacts on fish, wildlife, and related environmental values and enhanced these values where practical. Because of the nature of strip mining it is very difficult to minimize impacts to fish and wildlife populations since they are all removed during mining.

6. Restoring the recharge capacity to a condition that supports salmon spawning and rearing in reconstructed streams. None of the citations provided by ADNR indicated how or if the recharge capacity was restored. There are no salmon in streams in these mining areas. The warm water fish species found there have completely different life histories and habitat requirements than salmon and do not require upwelling ground water for spawning or overwintering.

For the aforementioned reasons reclamation at these two mines does not demonstrate that reclamation of salmon producing drainages in the Chuitna watershed, that restoration of fish productivity to pre-mining levels and that compliance with Alaska Surface Coal Mining regulations is technologically feasible after coal strip mining.
References:


Conclusion

None of the projects cited by Commissioner Sullivan in his rejection of the Unsuitability Petition demonstrate the technological feasibility of reconstruction of a salmon producing drainage with its associated riparian areas, aquifers and wetlands, and the creation of an entirely new salmon spawning and rearing stream with its associated confined and unconfined aquifers on top of 300 feet of porous mine overburden. Furthermore the projects cited by ADNR fail to demonstrate strip mining through streams in the Chuitna watershed is consistent with the requirements of the Alaska Surface Coal Mining Control and Reclamation Act Regulations regarding avoidance of impacts and reclamation. The strip mines used as examples by ADNR did not impact or restore anadromous salmon stocks or their habitat. Strip mining has much greater impacts on anadromous salmon habitat than the placer mines cited by ADNR. Restoration of a strip mined salmon producing drainage would be exponentially more difficult than grading dredge spoils, revegetating stream banks, and attempting to confine an unstable placer mined stream to a single channel. In fact there is no evidence in ADNR’s rejection of the Unsuitability Petition or anywhere in the scientific literature that a strip mined salmon stream and its drainage have ever been recreated on top of several hundred feet of mine overburden. Reviewers need to keep in mind that all of the techniques cited as examples by ADNR including riparian revegetation, spawning channels, fertilization, channel relocation, channel reconstruction etc. were developed in the Pacific Northwest and British Colombia in an attempt to halt or reverse the continuing decline of anadromous salmon populations. None of these techniques have succeeded even though hundreds of millions of dollars have been spent on reclamation. If the techniques cited by ADNR worked they would have been used everywhere and salmon populations would be increasing. The problem is that from a salmon habitat perspective, the effect of permanent landscape changes such as the deep strip mining proposed for the Chuitna River drainage probably cannot be reversed (Lackey, 2000).

References:

November 11, 2011

To: Robert Shavelson
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From: Margaret A. Palmer
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RE: Expert Comments on Denial of Unsuitable Lands Petition (ULP) by Alaska Department of Natural Resources (DNR) dated 10/24/11

I outline the science evidence that reclamation of streams and wetlands is NOT technologically feasible for the proposed Chuitna mine watershed. Specifically, current and highly relevant science shows that the scientific technology and knowledge is not sufficient to reclaim salmon streams and riparian habitats post-mining in the Chuitna Watershed. Therefore if the mining proceeds, the damage done to streams and wetlands will be permanent – the damage is irreversible.

Section I. Evaluation of the reclamation examples cited by DNR
A number of projects were referenced by DNR and PacRim as evidence that it is technologically feasible to reclaim wetlands and streams in a manner suitable for the proposed mine site at Chuitna. In some cases, these projects have been referred to as restoration projects and so that term may be used in my comments since restoration is part of a reclamation process. As the Commissioner himself stressed in the decision document, it is important that competent and scientifically sound data are used in such decisions. We fully agree but further emphasize that the universally accepted method for ensuring that scientific information is sound and unbiased is the peer-review process. For this reason, it is critical that studies which have been vetted by the external scientific community be weighed more heavily than material produced without external peer review.

The basic arguments put forward by the Commissioner are that 1) there are many examples of successful stream reclamation that are analogous to what will be done on the Chuitna site, and 2) that reclamation technology has advanced significantly since the 1990 FEIS suggesting that criticisms used in that FEIS are no longer applicable. The findings from my expert evaluation of the examples provide in the DNR petition denial are that the examples are not relevant to the type of reclamation required for the Chuitna mine site, particularly for Stream 2003 and its tributaries. For each specific example, I outline below why they do not provide evidence that reclamation of stream 2003 and the broader
watershed is possible. In general, the example projects cited involve streams that were only minimally impacted compared to what will occur for stream 2003.

**Diamond Shamrock Project.**
The DNR denial drew heavily on the 1987 permitting decision for this project as well as EPA’s 1990 FEIS and ROD on this project. Yet this 1987 project was nothing like what is being proposed for the Chuitna site and the logic that was used in the DNR denial to suggest that Chuitna is technologically feasible was highly flawed for the many reasons; I provide a few examples:

- Shamrock was restoration project on a stream reach that had been diverted...not disconnected (destroyed) from the river network.
- Requiring that sediment and drainage controls (including ponds; page 51 of DNR denial) be put in at a mine site place does not ensure they are working effectively nor does it prove reclamation is feasible.
- There is no explanation of what ‘design’ could ‘prevent material damage to the hydrologic balance’ (page 52) given that the groundwater flow paths in the mined area will be fundamentally altered and there is no evidence they will recover within the time span that post-reclamation monitoring and assessment is occurring. On the contrary, there is evidence that it will take much longer and may never be sufficient to provide baseflow to created streams (Myers 2011).
- The DNR denial cites (page 17) a “conclusion” by EPA that ‘wetland net productivity would be as high or higher and ‘therefore adverse impacts to primary wetland productivity would not be significant on a regional scale’. And Interruption of food webs in the immediate vicinity is not problematic because there are a large number of wetlands outside the remaining area’. This logic is flawed for many reasons including the following:
  - 1) the goal of ecological restoration (reclamation) is not to increase some ecological function like productivity but to restore it to within the range of variability in pre-impact levels (Hughes et al. 2005). Having higher (or lower) productivity is not a scientifically sound goal...it is arbitrary. The reclamation goals must be based on the pre-disturbance characteristics (level of productivity) and process rates of the system (Falk et al. 2006). There is a delicate balance within ecosystems between primary productivity, secondary productivity, and decomposition. Increasing production is not always good (e.g., eutrophication is basically the result of excess productivity that has cascading effects eventually causing collapse of entire aquatic ecosystems).
  - 2) Assuming that the remaining wetland areas will function as they did pre-mining ignores the large body of science on the negative ecological impacts of fragmentation (Henry and Amoros 1995; Kondolf et al. 2006).

**Valdez Creek stream reclamation**
This reclamation project was completed in association with placer mining from 1983-1995 in which a stream had been mined 180-200 feet below the stream surface. This reclamation project is NOT evidence that the proposal for Chuitna reclamation of streams is technologically feasible. The Valdez Creek mining operations and impact to the stream are extremely modest in comparison to what is proposed for Chuitna Stream 2003. As the EPA Site Visit Report¹ from 1992 emphasized Valdez creek was diverted around the mine site and rejoined the natural stream after about 1 mile:

“Mining operations are concentrated on the lower portion of the valley, two miles upstream from the Susitna River. In this area, Valdez Creek has been diverted by the mining company in order to access to ore beneath the active stream channel (see Section 3.2). A diversion dam has been constructed upstream of the active pit. The dam impounds water, which then flows through the diversion channel approximately one mile until rejoining with the stream. The diversion channel is lined and covered with rip-rap. The Creek is then returned to its original channel below the mine, before entering the Susitna River.”

Key points:
- Valdez Creek was not destroyed by mining operations from its headwaters to its confluence with downstream tributaries as is to be the case for the Chuitna 2003 streams (Figure 1).
- Water flow into the diversion channel was from the un-impacted streams above the mine or from groundwater wells.
- Fish inhabiting Valdez Creek are not salmon but instead grayling and lake trout. Further, during the normal time for migration upstream, the fish only had to be transported ~ 1 mile from a pond below the mine site to just above the diversion dam.
- Valdez biota (and ecosystem processes such as primary production) did not have to fully recover in a channel that had been constructed de novo over a mined area.
- Reclamation of Valdez did NOT required construction of 2 miles of stream as PacRim suggests; the stream remained intact with only a short diversion section.

Figure 1. A portion of the Chuitna River Basin showing the proposed mining boundary in green. Note that the mining plans will result in the destruction of multiple tributaries of Stream 2003 all the way from their source (headwaters) to their junction with larger streams. Further, the flow paths to those streams will be completed changed since the entire watershed region will be mined, including major loss of wetlands that collect and store water that recharges the groundwater.
Granite Ponds, near Granite Creek, AK
This project was focused on reducing sedimentation from gravel mining operations. Gravel pits were converted to ponds to act as settling traps for the sediment that otherwise might enter the stream. However, the stream was never impacted beyond this—it was certainly not destroyed completely or mined-through and there was never any stream creation involved. Additionally the impacts that did exist were not in headwater streams, so this project is not relevant to the type of reclamation proposed for the Chuitna Stream 2003.

Resurrection Creek
The impacts to this stream were modest compared to what is proposed in the Chuitna case. Small-scale hydraulic and shovel mining was done in Resurrection and tailing piles that impacted the floodplains contributed to stream straightening. These tailings did disconnect the floodplains and wetland from the stream in the lower portion of the Creek. However, the stream was not mined through to disrupt groundwater flow paths and in general, the channel itself did not undergo earth-moving activities such as filling sections, rerouting water or bull-dozing reaches. The reclamation involved two primary activities: reconnecting the floodplains to the active channel and adding meander bends to the channel (and as with all stream restoration projects, vegetation was planted after the floodplain and channel work was completed). These primary activities are nothing like what will be required for the proposed Chuitna project where the large areas of the valley will be mined through 100’s of feet (thereby disrupting flow paths) and some of the headwater tributaries to stream 2003 will be completely destroyed. This is nothing like the Resurrection case where the channel and water flow paths remained intact. Further, floodplain re-grading and adding meander bends to streams like Resurrection is an extremely common practice and nothing like stream creation which I discuss later in this report. Interestingly, as I point out later (Section xxx), even these common practices have not been shown to lead to full ecological recovery. Restoration of channel form is not the same thing as restoration of channel process as I discussed extensively in Palmer 2009 Report on Chuitna Mine project by PacRim.

Moose Creek
This Creek had experienced some re-routing at different points in time, had portions that had been straightened and channelized (separating it from its floodplain) and the alterations also resulted in waterfalls, which prevented salmon access upstream. The restoration project consisted of “reconstructing two river reaches to bypass several waterfall barriers, 2) restoring channel connectivity to the adjacent floodplain; and, 3) re-vegetating the riparian habitat along the reconstructed reaches”². In short, it was a fish passage project combined with some floodplain re-connectivity work and replanting of vegetation. The restoration did not involve the elements so critical to the proposed Chuitna project: channel creation, reclamation of major portions of the floodplain and restoration of the groundwater inputs. The impacts of the proposed mining activities are vastly more extensive including destruction of forest, wetlands, watershed-wide habitat for wildlife, headwater stream habitat for aquatic species, and the entire loss of 17.4 km of streams that support healthy populations of invertebrates and fish, including many highly valued salmon and other game fish.

Nome Creek
This stream had been disturbed by long-ago placer mining activity within the watershed that included excessive sedimentation into the stream, some diversion of the stream through ponds (settlement ponds) or side channels. The restoration consisted of removing the ponds and side channels as well as

² [http://wildfish.montana.edu/Cases/browse_details.asp?ProjectID=73](http://wildfish.montana.edu/Cases/browse_details.asp?ProjectID=73)
re-grading the floodplain and re-vegetating the riparian zone\(^3\). Once again this is not an example relevant to the proposed Chuitna reclamation work because the channel was not mined through to great depths, there was no stream creation involved, and the longitudinal connectivity of the water course of Nome Creek remained intact.

**Clear Creek**

This salmon stream in California was subjected to hydraulic and dredge mining along with gravel mining disturbed the floodplain, created pits and ponds that became isolated when water levels were low and fish got stranded in these at times. Additionally piles of tailings were left along the stream channel. In 1963, a dam was built on Clear Creek that resulted in substantial decline in natural flow variability in the stream – flood flows were lost entirely yet they are believed important for conditioning the stream bed and substrate for spawning sites. Restoration involved filling of the pits and re-grading floodplains so fish could not be stranded, replanting riparian vegetation, increasing releases from the dam to restore part of the historic flow variability, and adding spawning gravel to the streambed\(^4\). While this stream did support salmon and the project resulted in benefits to the salmon population, the project in no way resembles the Chuitna project because it was not a headwater stream, it was impacted by dams not by mining at the scale the Chuitna operation, and, it did not have its groundwater flow paths fundamentally altered in the manner that will occur in the Chuitna watershed. In short, the Clear Creek project primarily involved removal of tailing material along the channel, providing a means for fish passage, adding rock material to the streamed, and increasing flow releases from a dam to the stream. This does not resemble the type or magnitude of reclamation that would be needed for the Chuitna sites. The technologies employed for Clear Creek are not technologies that would solve the problems created by the mine impacts at Chuitna.

**Silver Bow Creek**

This creek was impacted by flood-delivered mine wastes and tailings (with heavy metals in them) coming from mining in the region done during the 1800’s. This was declared a Superfund site and resulted in a ‘reclamation project’ consisting of excavating the contaminated floodplain and surrounding soils. After the excavation, the floodplain was re-graded, the channel reshaped in some places, and riparian replanting (‘greening’) undertaken. The heavy equipment was primarily used to remove the millions of cubic meters of contaminated soils and sediments, some habitat ‘improvements’ were made by adding curves to the stream and varying the channel depth\(^5\). It is understandable that this is a project to be proud of because of the removal of so much seriously contaminated material that had been allowed to accumulate in the floodplain and parts of the channel. But this was a Superfund clean-up and post-sculpting project, NOT a channel creation project. It is not clear why the DNR denial refers to this as the ‘complete reconstruction of 10 miles of trout streams’ since the channel was always in place (albeit polluted).

**Reclamation examples from Illinois and Indiana:**

The **Burning Star** case involved eight miles of stream that had been impacted by dragline placed mine spoil. The **Pipestone Creek** project involved “restoring” 4.6 miles of stream on reclaimed mine spoils. The **Pyramid State Park** project involved impacts to land (not streams) and the **Discovery #2 Mine**

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\(^3\) Kostohrys, John 2007 Water resources and riparian reclamation of Nome Creek, White Mtns Nat’l Rec Rea, Alaska. BLM, Alk. Open File Reort 113, 49 pages (citation 360 in DNR denial)


(Vingo Coal) project was a land reclamation project (again, no streams). While these projects were done on mining sites, the projects have no relevance to the reclamation to the Chuitna case for the following reasons:

- Several of these reclamation projects did not even include streams (Discovery, Pyramid)
- For those with streams, they are warm-water streams and do not support sensitive, anadromous species such as salmon (Burning Star, Pipestone)
- the watersheds do not have bogs or fens (all four sites)
- Like many of the other projects discussed above, sections of the streams were diverted around the mine during the mining process but the upstream reaches were intact and the diverted reaches always connected to upstream sources and associated groundwater recharge areas.
- These streams and the catchment areas of their headwaters were not mined through as proposed for Chuitna.

Summary Section II. The results of my analysis of the reclamation examples cited by DNR and PacRim as evidence of the feasibility of reclamation at the Chuitna site clearly show that these examples do not demonstrate technological feasibility for the Chuitna site for a number of important reasons. The examples did not deal with situations that required anything close to the level of technology that would be needed to attempt reclamation at the Chuitna site. Many of the examples involved diverting a portion of a stream channel around a mine site such that the connectivity of the streams was not disrupted as will be the case for Chuitna. The examples did not involve complete destruction of the drainage area to entire tributaries. The examples did not involve the types of fragile wetlands present in the Chuitna site.

Section II. Scientific evidence that reclamation is not feasible
The status of research evaluating the effectiveness of stream and wetland restoration/reclamation has advanced significantly in the last decade and there is now clear evidence of widespread ecological failures of restoration projects attempted on sites far less damaged than what will occur at the Chuitna site. If reclamation technology is not adequate to restore basic ecological structure and function (e.g., pre-degradation levels of water quality, biodiversity or ecological processes) in watersheds that are significantly less degraded than the Chuitna watershed post-mining, then it is certain that reclamation is not technologically feasible at Chuitna.

Demonstrating technological feasibility of a reclamation effort requires quantification of the ecological outcome. “Site walks”, photos, and subjective assessments of other reclaimed areas are NOT sufficient to demonstrate that it is technologically feasible to restore biodiversity or other ecological attributes – the problems with such subjective approaches have been extensively documented (e.g., Bernhardt et al. 2005, Bernhardt et al. 2007, Jahnig et al. 2011). Further there is an extensive literature on methods for assessing the ecological effectiveness of projects. This point is raised to emphasize why it is critical to use the peer-reviewed literature to address the question of technological feasibility.

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7 The most common metric for evaluating the ecological outcome of a stream restoration project is to sample the benthic macroinvertebrates. The communities of invertebrates are believed to provide an
The Commissioner’s statement in the ULP denial (page 54) that: “petitioners fail to provide convincing evidence ...that anything has changed since DNRs 1987 Permitting Decision...” is quite simply incorrect. In my 2009 statement (Palmer 2009 Chuitna report), I provided an extensive description of peer-reviewed journal articles documenting major ecological failures of restoration projects on streams. I will not repeat a description of the examples I provided in my 2009 statement but instead: 1) list the peer reviewed articles that describe those examples I provided, and, 2) provide brief descriptions of additional examples that have emerged since I wrote the 2009 statement.

I emphasize that the following list are of reclamation projects that have failed ecologically – these projects are NOT listed to suggest that the sites or types of degradation associated with the examples are directly similar to the Chuitna project – instead, it is the fact that all of these projects were completed under far less technologically challenging circumstances and yet they still failed. Thus, these peer-reviewed articles provide a very clear indication of the technologically limited state of the field of stream restoration.

**Peer-reviewed articles quantifying the technological limitations of reclamation and lack of data on positive outcomes:**

**Cited in Palmer 2009 Expert report on Chuitna**

aggregate view of in-stream conditions because they respond to a variety of different stressors and integrate the impacts of those stressors over time (Barbour et al. 1996, Bonada et al. 2006). A number of macroinvertebrate bioassessment tools have been developed and they typically employ a suite of metrics that may include measures of richness (e.g., number of total taxa, number of EPT taxa, i.e., Ephemeroptera, Plecoptera & Trichoptera), composition (e.g., % EPT taxa, % Diptera), and/or tolerance (e.g., % dominant taxon, % tolerant taxa; Barbour et al. 1999)). Many studies have linked one or more of these metrics to land use, and more generally, stream condition (e.g., Barbour et al. 1996, Hawkins et al. 2000, Moore and Palmer 2005, Purcell et al. 2009, Stephenson and Morin 2009, Walsh et al. 2005, Walters et al. 2009). Fish bioassessments are frequently conducted because of the cultural and economic importance of these animals (Barbour et al. 1999) and such assessments are critical to evaluating the technological feasibility of restoring salmon to the Chuitna streams post-mining. Similar examples could be provided for wetland creation and I include a few references to that literature (e.g., Turner et al. 2001, ELI 2006, Kihslinger 2008).

New or not sited (in previous Palme report) peer-reviewed articles

Peer-reviewed article on aquatic reclamation projects on previously mined land
These studies are important because the reclamation project was done on previously mined land situated in an ecoregion similar to the Chuitna site and the goal of the project was to restore fish productivity. The Jones et al. study reports on fish response while the Scrimgeour study reports on efforts to enhance food availability (macroinvertebrate productivity) for fish.

[Excerpts from Jones et al.]
In 1991, diamonds were discovered in the remote region of the Northwest Territories of Canada known as the Barrenlands. In preparation for mineral extraction, two lakes and their connecting streams were drained to provide access to the diamond-bearing ore. As part of the habitat compensation agreement, a 3.4-km stream channel was blasted out of the granitic bedrock to reconnect the drainage network. Since 1997, water has been diverted around the two lakes, which became open-pit mines, through the constructed stream channel. An objective of these construction efforts was to replace the fish habitat lost during mine development. ...

We evaluated the initial success of this compensation program by comparing multiple biological attributes of the constructed stream during its first three years to those of natural reference streams in the area. The riparian zone of the constructed stream was largely devoid of vegetation throughout the period, in contrast to the densely vegetated zones of reference streams. The constructed stream also contained lower amounts of woody debris, coarse particulate organic matter (CPOM), and epilithon; had lower coverage by macrophytes and bryophytes; and processed leaf litter at a lower rate than reference streams. Species richness and densities of macroinvertebrates were consistently lower in the constructed stream compared to natural streams.

[Excerpt from Scrimgeour et al.] “Our assessments of the performance of the constructed stream during the first 3 years after its creation have shown that it was not a good surrogate for natural reference streams. .... To enhance secondary production to levels comparable with reference streams, a suite of engineered structures were deployed in late 1998 to create riffle habitats. .... [Results:] .... reference streams supported higher densities of Simuliidae and phemeroptera compared with engineered structures and unenhanced sites within the channel. Total biomass, biomass of Chironomidae, non-chironomid Diptera and combined biomasses of (i) Nematoda, Oligochaeta and Turbellaria and (ii) Ephemeroptera, Plecoptera and Hemiptera from reference riffles exceeded those at engineered structures.”

Jones et al. and Scrimgeour et al. conclude that the reclamation effort failed to produce the desired outcomes. By three years post-reclamation adult grayling were migrating through the channel and even spawning however the young graylings produced exhibited poor growth and production of young-of-year. The additional restoration actions that involved adding engineered structures to enhance secondary production (macroinvertebrates) to support fish were unsuccessful.

The fact that the target fish population productivity in this project – arctic grayling – did not recover has important implications for the Chuitna case because the grayling requirements for growth and reproduction are not as complex and stringent as that of the Chuitna salmon (Trasky 2011, Comments on ULP denial). As Trasky outlined in his report: “Salmon dig redds into the hyporheic zone but spawning grayling do not. Grayling broadcast their eggs which drift down to the stream bottom where
they develop. The eggs hatch within three weeks. It doesn’t matter if these streams go anoxic, dry up or freeze to the bottom during the winter because prior to freeze up both the adults and juveniles migrate out of these systems to deep rivers and lakes to overwinter. Furthermore grayling spawn annually so the loss of an entire year class does not have long lasting consequences.” If the reclamation/stream construction project on previously mined land in the NW Territories of Canada did not work for grayling who are not nearly as sensitive a salmon, it would be arbitrary scientifically to say something like this could work for salmon in Chuitna.

In short, if restoration is not possible on landscapes that have far fewer impacts to them than those proposed for the Chuitna River project, then we can say with certainty that such restoration efforts on the Chuitna post-mined land will not be possible.

Summary of Section II: These peer reviewed articles discuss major problems associated with successful restoration of streams and many provide quantitative data demonstrating ecological failures for restoration challenges that were far simpler than PacRim’s plan for the Chuitna watershed. The current status of the technology for stream and watershed reclamation is limited to small scales (usually single reaches of streams or small parcels of land), is only useful in intact water networks (e.g., projects may involve diverting streams but not restoring streams with no connectivity to headwaters), is not designed nor tested for situations in which the underlying soil/lithology/geology and associated groundwater flow paths are destroyed. Finally, stream creation on such parcels of degraded land has never been successfully demonstrated – indeed its feasibility has been seriously questioned (Palmer and Filoso 2009, Palmer et al. 2010, Fritz et al. 2010, Bernhardt and Palmer 2011,

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Report on Chuitna Coal Project of PacRim Coal

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March 16, 2009

This report is in relation to a proposed coal mining project that will impact the Chuitna River watershed which is situated near Anchorage, Alaska and to the west side of Cook Inlet. The coal is located in a 20,571-acre lease tract. The project will involve putting in access roads to the mining site, building housing, adding an airstrip, power facilities, logistics support facilities, and various other mining-related infrastructure (e.g., transport conveyors). The watershed is ~150 square miles but the area to be impacted is much larger due to all the infrastructure and access needs for mining.

As context for my comments, I am a Professor at the University of Maryland where I oversee a scientific research laboratory with approximately 120 staff, 20 buildings, and a research fleet (see attached Curriculum vitae). I have over 25 years of experience in research and teaching on coastal ecosystems, watershed science, and stream ecology and restoration. Past work includes leading a large team of scientist in developing the first national database on river restoration in the U.S., co-authoring a book on The Foundations of Restoration Ecology and serving as an expert advisor on the design of multiple stream and river restoration projects.

I have reviewed a number of documents including the 2007 Fish and Wildlife Protection Plan (Part D7), the Protection of the Hydrological Balance (Party D12), the Hydrology Component Baseline Report, the Annual Water Management Plans (Addendum D12-A), the Baseline Report for Vegetation and Wetlands, a Wetlands Functional Assessment, and portions of the 1990 Final Environmental Impact Statement by the EPA and other related documents including some appendices.
I begin with comments on the impacts of the mining activities; however, my report focuses primarily on concerns with the mitigation that is for the streams.

**Ecological impacts of the project**

The Chuitna River watershed is characterized largely by tundra vegetative cover, spruce-birch forest (almost 50% of the mine site), alder scrub, and various fen and wetland species. Many of the plants and habitat types are very sensitive ecologically and yet will be destroyed or degraded severely. The impacts of the mining activities include destruction of forest, wetlands, habitat for wildlife, habitat for aquatic species, and the entire loss of 17.4 km of streams that support healthy populations of invertebrates and fish, including many highly valued salmon and other game fish. Tributaries of the Chuitna River that will be impacted include in particular, the headwater stream called “2003 Creek” (sometimes called Middle Creek) which drains the mine site; other tributaries likely to be impacted include “Lone Creek” and “2004 Creek”.

**Critical habitat.** The areas to be impacted are in pristine regions of the watershed and while one could argue that all of the habitat types are critical ecologically, there are three that are unusually so: tundra, wetlands, and headwater streams (Elmqvist et al. 2003)

*Tundra ecosystems* are considered among the most fragile ecosystems on earth (Reynolds and Tenhunen 1996). They are extremely sensitive to disturbances (even dust from nearby roads), slow to recover (Myers-Smith et al. 2006) and a huge fraction of the carbon in tundra ecosystem is stored in soils (Mack et al. 2004) which will be severely disturbed by the proposed mining activity. Yet the ability to restore the tundra regions and peatlands after the Chuitna Coal Project is complete is highly questionable. Peatland restoration has not been studied very extensively but current work indicates that only under the following conditions are restoration efforts likely to be successful: some remnant vegetation, a seed bank [in the soil], and connection to other healthy peatlands (Gorham and Rochefort 2003). For much of the region that is impacted by the mining, these conditions will not be met.
Wetland areas are also well known as ecologically critical ecosystems. The reports from PacRim indicate that approximately 4,000 acres of wetlands are in the Chuitna Coal Mine mapping area and there are at least 7 plant species designated as ‘rare’ by the Alaska Natural Heritage Program. Wetland types include riverine lowlands, bogs, fens, and areas around ponds. The project is in a broad region of Alaska well known for its ecologically important wetlands (Tiner 2003). These wetlands have high rates of primary production and store large amounts of organic matter, both of which are critical to the overall food web of the region as well as to long term carbon storage (Chimner et al. 2002). Wetlands such as these support both photosynthetically-based food webs and food webs dependent on detritus (decaying organic matter) and are home to a very diverse community of permanent and migratory wildlife (Mitsch and Gosselink 2007). Such wetlands are also critical sites for water storage and groundwater recharge (Brauman et al. 2007). Finally, wetland ecosystems play pivotal roles in biogeochemical processes including nutrient transformations, denitrification, removal of some contaminants from the water, and decomposition (Palmer and Richardson 2009, see Table 1). There is an extensive literature on wetland restoration indicating that hydrological flow paths are essential to success and the Chuitna mining project will fundamentally alter these paths. Further, results from wetland creation efforts suggest that while mitigation projects may meet compliance requirements, full ecological or functional success is low or unknown for most projects (Ambrose et al. 2007; Eulis et al. 2008; Mathews and Endress 2008). A 2008 review prepared for Congress stated: “Both scientists and policymakers debate whether it is possible to restore or create wetlands with ecological and other functions equivalent to or better than those of natural wetlands that have been lost over time” (Copeland and Zinn 2008).

Headwater streams are those smallest of all tributaries that reflect ‘where rivers are born’ – that is, they feed the complex network of larger and larger downstream tributaries. Their position within watersheds (they impact all downstream waters), their high rates of key biogeochemical processes, and the high levels of biodiversity they support have been emphasized in a great deal of scientific research (Lowe and Likens 2005; Meyer et al. 2007). Headwater streams such as those that will be destroyed or impacted by watershed disturbance during mining may be small in size, but they provide habitats for a rich array of species, which enhances the biological diversity of the entire river system. This is discussed later but briefly: they provide a source of food and colonizing flora and fauna to downstream waters, they are important spawning and nursery grounds for fish and insects that live in larger rivers the rest of their lives, and they provide a refuge from predators and changes
in temperature for some species. Their role in biogeochemical processing and particularly nitrogen
dynamics is disproportionately related to their size (Peterson et al. 2001). As I discuss later, the
potential for headwater streams to be restored varies with the amount of degradation; however, there
is no scientific evidence that streams that are mined through in the manner PacRim proposed can
ever be restored ecologically.

**Biodiversity loss and functional consequences.** The loss of 17.4 km of streams will remove
habitat that is essential to the life cycle of salmonids and other groups of fish that reside all or part of
the year in the Chuitna tributaries. Mining through the streams to a depth of > 300 feet will lead to
severe and permanent environmental impacts to the existing channel and living resources. Attempts
will be made to re-locate valued fish but survival is not certain. Mobile animals like bear, moose,
and birds may be able to move to other areas when their local habitat is destroyed although some
mortality is inevitable. Flora and smaller fauna within the streams to be mined will be killed
including amphibians, invertebrates, algae, and microbial communities. Previous reports for the
Chuitna watershed indicate that invertebrates include not only taxa such as chironomids and simulid
blackflies (Dipterans) but sensitive insect taxa in the orders Ephemeroptera, Plecoptera, and
Trichoptera. Thus, biodiversity losses will be very significant in the streams that are mined and in
downstream reaches which are impacted by the upstream disturbances.

Biodiversity loss in the Chuitna watershed is of great concern not only because valued species will
be lost but because biodiversity is integral to ecosystem function. Biodiversity loss is often
associated with a decline if one or more ecosystem functions (Hooper *et al.*, 2005; Cardinale *et al*.,
2006) and since different species contribute differentially to different functions, the maintenance of
multi-functional ecosystems requires maintenance of high species diversity (Hector & Bagchi,
2007). Because diverse ecosystems are typically associated with higher functional and response
diversity (different species vary in their vulnerability and response to change), ecosystems with
many species exhibit more resilience in the face of environmental changes (Elmqvist et al. 2003).
Ecological resilience is the ability to resist perturbations or recover from disturbances such as
unusual climatic events (storms, droughts) or even anthropogenic disturbances (e.g., global warming,
tree harvest). Once biodiversity is degraded, ecosystems are more vulnerable to collapse due to
higher temporal and spatial fluctuations in species and performance; in short, species diversity
contributes to the stability of biotic communities and ecosystem function (Naeem et al. 1994; Tilman et al. 1996).

**Deficiencies of the Mitigation Plan**

The proposed mitigation includes the construction of artificial off-channel spawning and rearing habitat, off-site mitigation options (culvert improvements, bridge repairs, erosion control on the Theodore River, lake “enhancement”, removal of a dam on Fish Creek), and stream “reclamation”. I focus my comments on the latter since it is the only activity that directly addresses compensation for the destruction of the 17.5 km of Stream 2003 and associate tributaries.

The PacRim *Fish and Wildlife Protection Plan* describes the objective of fully reconstructing an “undisturbed” channel and floodplain to “ensure pre-mined ecological functions and values are restored” (page 15). A natural channel design (hereafter, NCD) or Rosgen approach is proposed. They will attempt to mimic the morphological attributes (channel dimension, pattern, profile) of a ‘reference reach’ that is selected from the existing, pre-mined channel. Their goal is to “replicate the pre-mine channel geometry…” (page 24). They have extensive data from geomorphic surveys, streambed particle size measurements, and habitat surveys and they have classified existing channels based on the Rosgen classification scheme. Stream 2003 is apparently not gauged at present and so they will estimate hydraulic parameters needed for the design. It also appears they do not have direct measurements of bedload or tractive force in existing channels but indicate they will get “direct sediment discharge collections across a range of flows” (page 24) in order to develop a sediment rating curve. Descriptions of the ecological aspects of the reclamation are extremely limited and mostly deal with riparian vegetation.

1. **Failure to directly assess ecosystem functions.** The mitigation plan does not include direct assessment of the ecological functions that will be lost when the streams are destroyed by the mining activities. Healthy streams are living, functional systems and the most essential ecological functions include: the purification of water, the removal of excessive levels of nutrients and sediments before they reach downstream waters, the processing of organic material (decomposition or biological utilization), and primary and secondary productivity (growth of photosynthetic organisms and
consumers) (Fischenich 2006, Allan and Castillo 2007). The most common stream functions are shown below in Table 1.

These functions are supported by ecological processes including: the processing of nutrients at the same rate and form as unimpacted streams, the decomposition of organic matter at rates typical of nearby unimpacted streams, and, microbial, primary and secondary production the same as nearby healthy streams (Palmer et al. 1997a; Naiman et al. 2005; Palmer and Richardson 2007). These processes must be measured in order to determine how and whether they may be brought back to the right levels and direction through restoration. No data or measurement plans for these processes are provided in the mitigation plan despite abundant scientific studies outlining how to make and interpret such measurements (e.g., Peterson et al. 2001; Gessner and Chauvet 2002; Hall and Tank 2003) and how such measurements can be used to evaluate the success of a restoration project (Buckveckas et al. 2007; Roberts et al. 2007).

Use of well-accepted methods for measuring ecological functions (e.g., see Hauer and Lamberti 1996, 2006) is important because ecological functions evaluate dynamic properties of ecosystems that underlie an ecosystem’s ability to provide vital goods and services (Gessner and Chauvet 2002, Falk et al. 2006, Fischenich 2006, Palmer and Richardson 2007). The units of an ecological function are a process rate and direction (Table 1). Functions reflect system performance (http://www.epa.gov/eerd/functional.htm) and their measurement requires quantification of ecological processes such as primary production or nutrient uptake (Hauer and Lamberti 1996, 2006). This should be reflected in the mitigation plan if the plan is to mitigate functions that are lost due to the mining through of streams. Functional measures have been used to compare degraded vs. restored vs. reference streams¹ and have been shown to be quite sensitive to degradation and restoration.

<table>
<thead>
<tr>
<th>Ecosystem function</th>
<th>Ecological Process that supports this</th>
<th>Measurements required</th>
<th>Without it what happens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Purification</strong></td>
<td>Biological uptake and transformation of nitrogen, phosphorus</td>
<td>Direct measures of <em>rates</em> of transformation of nutrients; for example: microbial denitrification, conversion of nitrate to N₂</td>
<td>Excess nutrients can build up in the water making it unsuitable for drinking or to support life</td>
</tr>
<tr>
<td><strong>Water Purification</strong></td>
<td>Biological removal of materials such as excess sediments (removed by riparian plants for example) or such as toxins (some taken up by plants or processes by microbes thereby removing them from the water)</td>
<td>Direct measures of contaminant flux (e.g., the movement of sediment into and down streams). This is a <em>rate</em>.</td>
<td>Toxic contaminants kill biota; excess sediments smother invertebrates (kill them), foul the gills of fish (kill them), etc; water not potable</td>
</tr>
<tr>
<td><strong>Decomposition of organic matter (organic matter processing)</strong></td>
<td>The biological (mostly by microbes and fungi) degradation of organic matter (could be leaf material or other input such as sweater or organic wastes)</td>
<td>Decomposition is measured as a <em>rate</em>. Usually expressed as the slope of a line showing weight loss over time of organic matter heated to high temperatures to convert the particulate carbon to gas (CO₂)</td>
<td>Without this, excess organic material builds up in streams, leading to low oxygen levels which leads to death of invertebrates and fish and the water is not something anyone would want to drink</td>
</tr>
<tr>
<td><strong>Production (Primary = algae &amp; aquatic plant; Secondary = growth of organisms like insects, fish, etc)</strong></td>
<td>Measured as a rate of new plant or animal tissue produced over time</td>
<td>Primary - measure the <em>rate</em> of photosynthesis in the stream; for secondary, you measure growth rate of organisms</td>
<td>Primary production supports the food web; secondary production (fish) we often eat or it (inverts) supports fish.</td>
</tr>
<tr>
<td><strong>Temperature Regulation</strong></td>
<td>Water temperature is “buffered” (i.e., does not change dramatically) if there is sufficient infiltration in the watershed &amp; riparian zone (due to vegetation) AND shading of the stream by riparian vegetation keeps the water cool.</td>
<td>Measure the <em>rate</em> of change in water temperature as air temperature changes or as increases in discharge occur.</td>
<td>If water infiltration or shading reduced (due to clearing of vegetation), the stream water heats up beyond what biota are capable of tolerating (due to high sunlight reaching the stream and an increase in overland runoff)</td>
</tr>
<tr>
<td><strong>Flood Mediation/Control</strong></td>
<td>Slowing of flow from land to streams so flood frequency and magnitude reduced; intact floodplains buffer increases in flow. The flow spreads out over floodplain &amp; energy absorbed; also healthy riparian vegetative cover in the watershed increase infiltration into soils and uptake of water (e.g., by plants) before it reaches the stream</td>
<td>Measure the <em>rate</em> of infiltration of water into soils OR discharge in stream in response to rain events (discharge = <em>rate</em> of water flow measured in volume per time…m³/sec)</td>
<td>Without the benefits of floodplains, healthy stream corridor and watershed vegetation you see increased flood frequency and flood magnitude</td>
</tr>
<tr>
<td><strong>Biodiversity support</strong></td>
<td>All of the processes above contribute to the maintenance of biodiversity. For example, primary production and the flux of organic materials into streams help support diverse living assemblages</td>
<td>Measure the number of species and how abundance varies among them; this function is not a rate per se but because it is critical to the support of all other functions, it is included in the table.</td>
<td>Headwater streams support extremely high biodiversity and many rare species that contribute food for higher trophic levels and help maintain functions such as organic matter processing</td>
</tr>
</tbody>
</table>
2. **Channel creation approach outside the scope of accepted science.** The Chuitna mining project will destroy fully healthy Alaskan streams in a relatively pristine region as they clear approximately 5000 acres and mine through the streams. During this process they will divert water from the streams then dig through the streambed and surrounding area to remove more than 300 feet of ‘overburden’ so they can reach the coal seams. Many years later, they will replace the overburden, add topsoil back, and use heavy machinery to construct a channel that has similar dimensions (width, depth, slope, sinuosity, etc) to the one they destroyed. Thus they will attempt to create a stream after all the natural flow paths and landscape topography have been destroyed. This is not even in the realm of anything that has been scientifically tested and is certainly not within the realm of what is considered ecological restoration. In practice, ecological stream restoration varies along a continuum from: removing on-going impacts to a stream (e.g., preventing toxic inputs) and letting the system recover on its own; to enhancing in-stream habitat or the surrounding riparian zone (e.g., adding coarse woody debris to streams and planting vegetation) in an otherwise healthy stream; to full scale restoration that involves manipulations of an existing stream channel (e.g., re-grading banks and planting trees along a stream with eroding banks) (Williams et al. 1997, FISRWG 1998, Karr and Chu 1999).

While the plan refers to this proposed mitigation project as “reconstruction”, it is in fact a new channel construction or creation plan. While the latitude and longitude of the streams may be similar to what they were before, everything else that defines an ecologically healthy stream will be gone or will have been dramatically altered at the end of the mining period (e.g., flow paths, riparian soil and streambed biogeochemistry, groundwater-surface water (hyporheic) exchange rates, mature riparian vegetation, etc). The mining project is a major earth-moving project that will impact a significant amount of land. While they outline plans to attempt to restore recharge capacity of the lands, these plans are based on assumptions and model output that even if correct, in no way assure restoration of the hydrologic and biogeochemical properties that the riparian, streambed, surface water, and hyporheic zone flora and fauna presently rely on. There is no evidence provided that the groundwater-surface water exchange, the concentration of suspended sediments, or the water quality in the new channel will be similar to what is in the undisturbed streams presently.
Based on my work leading a national project that developed the first comprehensive database on stream and river restoration for the U.S. (38,000 projects in the database; Bernhardt et al. 2005, Palmer et al. 2005) and on my extensive work with scientists and restoration practitioners, I do not know of a single case in which building streams in the manner they outline has been shown to work much less fully compensate for ecological functions lost when a stream is destroyed. Contrary to suggestions made in the mitigation plans, the very concept of creating streams with levels of ecological functioning comparable to natural channels on sites that have been mined-through as they propose remains untested and quite unlikely to succeed.

Interestingly, from the plan prepared by PacRim, there seems to be a clear understanding that what they propose is outside the accepted range of current science and practice. From page 14 of the Fish Protection Plan:

> “Historically the majority of stream restoration practice has involved alterations of modifications of an existing water body that has been impaired in some way. Stream 2003 and other Chuitna Coal Mine area stream represent a more comprehensive restoration effort that includes 3-D restoration of the entire channel including floodplain structure and form” (page 14).

In other words, they acknowledge that what they propose is not typical NCD type restoration, which involves alterations of existing channels, but instead goes well beyond what has been done in other settings. This leaves us with determining if they provide any new evidence of the feasibility of their mitigation streams. They do not. There are no data provided in the plan, nor are there peer-reviewed scientific studies referenced that demonstrate healthy streams can be created after this level of impact to the land has occurred. Even with far less damage to a site, stream restoration projects that involve channel modification have an extremely high failure rate (Smith and Prestegaard 2005; Tullos et al. 2009; Palmer et al. 2009).

3. Morphologically based channel designs are not ecologically based. The mitigation plan argues that they will use the Natural Channel Design (NCD or Rosgen approach) approach for constructing stream 2003 which is based on ‘tested methods’ (page 29, Fish Protection Plan) that will “ensure pre-mined ecological functions and values are restored” (page 13). But the NCD
approach to stream restoration has in fact never been evaluated for its ecological effectiveness. This approach was designed by Rosgen (1994) to address channel stability based only on building a channel structure (shape, slope, etc) that is able to transport the sediment and water inputs that are expected to be delivered to the stream prior to completion. There is no scientific evidence supporting the assumption that restoration of channel form will lead to full restoration of function (Palmer et al. 1997; Hilderbrand et al. 2005; Falk et al. 2006). How a stream looks (its form) is simply not the same as how it processes (its function) material and supports life (primary producers, invertebrates, etc). The present mitigation plan provides no evidence that restoration of channel form will lead to restoration of function.

Not only does the plan assume that selection of a channel type (e.g., “D channel”) from a channel classification scheme such as those proposed by Rosgen (1994) will necessarily result in full ecological restoration, but it also assumes that use of the NCD or Rosgen approach guarantees successful creation of a channel from a geomorphic and hydrologic perspective. However, channel designs based on a classification system that has not been fully evaluated at the site can lead to serious failures (Smith and Prestegaard 2005). As indicated in Palmer et al. (2005): “Attempts to develop restoration designs based on application of a single classification system across many environments have led to many failures in North America (e.g., Kondolf et al. 2001), because the specific processes and history of the river under study were not adequately understood.” If the mitigation projects fail and channels are unstable, this could cause new environmental degradation. However, even if they are geomorphically stable, this does not address restoration of function. Indeed, the Rosgen scheme of classification does not deal with ecological functions at all.

The Rosgen classification is based on channel morphology and uses a hierarchical key to demarcate stream types based on specified ranges of quantitative variables, including entrenchment ratio, bankfull width:depth ratio, channel sinuosity, gradient, and dominant substrate (Rosgen 1994). While use of the Rosgen scheme for stream restoration has been very common in the past, current science (published in many peer-reviewed scientific journals) has documented numerous reasons that use of this scheme for restoration can be extremely problematic (Gillilan 1996; Miller and Ritter 1996; Shields et al. 1999; Doyle and Harbor 2000; Kondolf et al. 2001; Juracek and Fitzpatrick 2003; Niezgoda and Johnson 2005; Smith and Prestegaard 2005; Slate et al. 2007; Simon et al.
2007; Roper et al. 2008). In fact, an analysis of > 75 channel reconfiguration projects overwhelmingly showed that restoration of biodiversity failed (Palmer et al. 2009).

The fundamental problem with classification based restoration approaches is that they assume fixed endpoints and rigid classification schemes in which the type of stream desired can be achieved by constructing a specific channel form. Yet, streams are living systems – far more than rock-lined ditches. Even from a practical point of view, restoration is far more than creating some design based on external appearance. The fundamental distinction between form and function of stream channels is not acknowledged by the plan, which focuses on structural aspects of the channels and ignores functional aspects. The method in no way takes into account a whole array of biophysical factors that determine the ability of the channel to support all of the living resources in pristine streams in the area. Such factors include: intensity and duration of sunlight reaching the stream, which is determined in part by the vegetative structure; inputs of organic matter upon which the food web depends; nitrogen and carbon levels in the soil and streambed; etc.

4. **Downstream impacts are not addressed.** The mining activities will fundamentally and permanently alter the chemical, hydrologic and sediment regimes which are master variables controlling the suitability of running-water systems for supporting downstream reaches. Further, since watersheds act as a unit and a considerable amount of land in the watershed is to be cleared, the impacts are expected to extend far beyond the mined-through streams. Even if the overburden and topsoils are stored during the mining for use later during reclamation, they will not have the same biogeochemical properties as prior to disturbance. Many of the soils in this region are highly organic. Disturbing them will result in dramatic changes including different microbial communities, alterations to the soil C:N:P content and changes in porosity. Even given the planting (reclamation) that is proposed, there is no clear evidence that conditions would be likely to return to pre-mining mature conditions. Biogeochemical processes in watershed and riparian soils influence the delivery of nutrients and other materials to streams and because these processes are greatly influenced by the flow rates and paths that water takes as it moves through surface and subsurface soils, disruption of the magnitude proposed for this project will certainly alter water quality. Even actions that are less disruptive than the mining that is proposed such as road building and land clearing) are well known to influence water quality and the movement of materials to downstream waters (Naiman et al. 2005; Nadeau and Rains 2007).
Since the streams to be destroyed are primarily headwater streams which play disproportionate roles in nutrient processing and supporting biodiversity, it is particularly problematic that > 17 km of them will be destroyed and yet the ability to re-create them is unlikely. Because headwater streams provide food (organic matter and prey) for biota in downstream waters, when they are lost food supplies are likely to be inadequate downstream (Wipfli et al. 2007). This is particularly the case if surrounding riparian vegetation is lost, which will be the case for Creek 2003 and some of the other streams within the mining area. This could result in decreased growth of fish and other organisms (Freeman et al. 2007) in the Chuitna waters. Biota may also be subjected to higher rates of suspended sediment and other forms of water quality impairment since sediment flux and dissolved constituents post mining are unknown.

Thus, the massive disturbance to the entire watershed, but particularly headwater streams, will have impacts in downstream waters. Changes in key ecological processes can have cascading effects on nearby ecosystems, particularly in river networks where the movement of materials can effectively link very distant ecosystems (e.g. headwater streams to rivers). For this reason, ecologists have increasingly focused research on broader spatial contexts and multi-scale processes (Palmer 2009). Nakano and Murakami (2001) showed that across-habitat prey flux accounted for 25.6% and 44% of the total annual energy budget of bird and fish assemblages in a Japanese stream. Subsidies such as these have been extensively studied both theoretically and empirically (e.g. Polis and Hurd 1996).

**Summary of Major Conclusions**

This is a very large project that will seriously impact a sensitive ecosystem that currently supports highly valued fisheries, rare plant species, and ecologically important habitats including wetlands and streams. The wetland and stream ecosystems that will be lost or damaged perform essential functions in the provision of important ecosystem services and it is very unlikely (and no evidence is provided to indicate) that the ecosystem functions can be recovered. The surrounding habitats such as the tundra are extremely fragile and as the project proceeds the risk that surrounding habitats will suffer direct or indirect degradation will increase. Across all habitats, but particularly the aquatic
ones, biodiversity loss will be substantial yet this diversity is critical to ecological functions that ensure the long term health and stability of the ecosystems. Basic concerns about the mitigation plan fall into four categories. First, the applicants have not directly measured ecosystem functions and thus have not applied current science to the mitigation issues. Without these functional assessments, they do not know exactly what natural resource values are being lost and thus what they need to mitigate for. Second, the approach proposed for replacing the lost streams (especially Stream 2003) is outside the realm of stream restoration or rehabilitation practices. Their approach basically amounts to channel “creation” in an area in which the earth has been disturbed to depths of 300-500 feet, the natural flow paths destroyed, and landscape topography reshaped. Channels that are created on these mined sites may have the same latitude and longitude of the original streams however everything else that defines an ecologically healthy stream will be gone or will have been dramatically altered. Third, the channel creation plans are based on a method (Natural Channel Design) that is morphologically based (reference templates) but there is no evidence that creation of channel form (pattern, plan, profile) will lead to restoration of ecological function. Indeed, there is ample evidence in the peer-reviewed literature that the approach they propose is problematic and that ecological outcomes typically fail. Fourth, impacts to the watershed and the headwater streams from the mining activities will fundamentally alter the chemical, hydrologic and sediment regimes which are master variables controlling the suitability of running-water systems for supporting downstream reaches.

In sum, based on the most current and rigorous science, the impacts of this project are very significant and there is no evidence that the restoration and mitigation plans that are proposed will either succeed or compensate for the natural resource losses.

**Literature Cited**


Report on Chuitna Coal Project Aquatic Studies and Fish and Wildlife Protection Plan

Prepared by Lance Trasky
Lance Trasky and Associates

August 17, 2009
Introduction
This report summarizes my review of the following list of documents related to the proposed Chuitna Coal Project.

(A) Aquatic Baseline: Existing Information for the Chuitna Coal Mine Project [Oasis Environmental, Inc.] (June 18, 2006);

(B) 2006 Freshwater Aquatic Biology Study Program [Oasis Environmental, Inc.] (April 4, 2007), including Appendices 1-8;

(C) 2007 Freshwater Aquatic Biology Study Program [Oasis Environmental, Inc.] (March 22, 2008), including Appendices 1-10 and Scanned Data Sheets;

(D) Wetland Functional Assessment [HDR Alaska, Inc.] (March 5, 2008);

(E) ASCMCRA Mine Site Permit Application, Part D7: Fish & Wildlife Protection Plan [PacRim Coal, LP] (July 2007), including all appendices;

(F) Agency correspondence concerning aquatic resources studies and study plans;

(G) 2008 Freshwater Aquatic Biology Study Program [LGL] [Jan. 2009].

My analysis of these reports focused on whether the aquatic resources studies were conducted using sound methodologies; whether the aquatic resources studies collected enough data and the right kinds of data; whether the aquatic resources studies provide an adequate understanding of the aquatic system; whether the reports provide an adequate foundation for a successful fish and wildlife protection plan; whether the fish and wildlife protection plan will successfully protect aquatic resources; and whether the aquatic resources studies provide adequate information for the U.S. Army Corps to make the required determinations under the 404(b)(1) Guidelines.
A. Aquatic biology: Existing information for the Chuitna Coal Project. Oasis Environmental 2006.


Analysis and Comments:
The existing information from the studies in the 1980’s provided in the summary is very limited. It isn’t clear if the original studies didn’t collect a lot of the types of data now known to be necessary to assess the impact of the project or if Oasis didn’t include everything in the summary. For example there is no information on phreatic and hyporheic groundwater flow investigations from the early studies.

Assuming that the 1982-1984 studies were equally rigorous, it would have been very helpful if the authors compared the data on fish and macro invertebrates to the data from the 2006-2008 studies in this summary. There are clearly differences in the number of adult Chinook, coho and pink salmon reported in the 1980’s and the present studies. Some of the data summarized in Figure 4 Timing of Life History Events for Salmonid Species in the Chuitna Drainage also raises similar questions. For example, the table indicates that chum and pink salmon fry emerged and out migrated from mid-February to mid-May. Did this data come from age zero fry collected during winter sampling in the early 1980’s? LGL did not report capturing any chum or pink fry in their winter sampling program in 2007-2008. As another example, the spawning period reported for coho from the 1982-87 studies as reported in Table 4 is September 1 through October 30. In 2008 LGL removed the weirs on Streams 2002-2003 and stopped counting adult coho on September 30. It is unclear whether this means that the timing of coho spawning has changed, that LGL missed a portion of the coho run, that the 1980’s data is incorrect, or something else.

Summary: There are significant differences in the findings of the 1980’s studies and the 2006-2008 studies. It is unclear if these differences are the result of changes in species composition, numbers and life history or differences in methodology.

Oasis’ study objectives related directly to fisheries:

1. Relative abundance, community composition, juvenile and adult distribution and spawning habitat
2. Water quality at trap locations and physical habitat evaluation locations
3. Channel morphology, habitat types, shape and substrate composition, and:
4. Human use of the fishery.

This information collected would be used to “assist with impact assessment” and “support project mitigation and reclamation plans. The channel morphology information would be “used to rebuild the affected streams to a level comparable with their original state and value.”

Analysis and Comments:

Executive summary:

Page xii paragraph: “Adult salmon distribution was determined by aerial and ground surveys.” Although aerial and ground surveys are often used to count salmon, these counts tend to underestimate the number of salmon present. There is within and between observer’s bias in aerial and foot survey estimates of spawning abundance of salmon (Jones et al 1998 and Bue et al 1998). The ability to see salmon from an aircraft is dependent on many factors, including light level, time of day, skill of the pilot, water clarity and depth, and stream bank vegetation. Aerial and foot counts tend to significantly underestimate the number of salmon present (by 25% to 68%) and are useful only as general indices of abundance (Jones et al 1998). To accurately determine adult escapement in the Chuitna River drainage, a weir or sonar counter is also needed at the river’s mouth. Counts should continue over 5 to 10 years because of the large natural fluctuations in population numbers and species composition over time.

2.2.1 Juvenile. Streams. Minnow traps: The 0.32 cm. mesh used to cover the minnow traps is large enough to allow age 0 salmonids to swim through it, so these fish may have not been accurately represented in the catch. Placing traps only in areas believed to be good juvenile salmon habitat likely biased the results.

2.5 Paragraph 2: If aerial surveys were impractical for estimating the number of adult salmon migrating up tributary streams due to poor visibility, and foot surveys were not used to estimate the number of spawning adult salmon, it is unclear how the estimates of adult spawning escapement in the tributaries were derived.

Ground surveys. Page 2.7. If lateral tributaries to streams 2002-2004 without minnow traps weren’t surveyed, how did Oasis conclude that no adults spawned there? ADF&G
Habitat Division staff found both spawning adult and juvenile coho salmon in first and second order tributaries to the Hoholitna River in the 1980’s.

2.5.1 Reference Reach Stratification page 2-14

2.5.2 Reach Selection Paragraph 3: Because of the great variation in stream morphology, stream flow, groundwater input, substrate, bank composition and other factors, it is not clear how a limited amount of data from a few hundred feet of stream channel in stream 2003 could be used to restore the 17.4 km miles of stream that will be excavated by mining. The report should also explain how information from streams 2002 and 2004 would be used in direct comparison to stream 2003 for restoration and rehabilitation purposes, since there appear to be substantial physical and biological differences between these streams.

It should be noted that Oasis also suggests that the data could be also used to rehabilitate streams 2002 and 2004 in the event that they are “inadvertently” impacted by mining. It seems likely that these streams will also be impacted by mining to some degree. Studies from other strip mines show that mining within a watershed – as will occur here in portions of the 2002 and 2004 watersheds -- affects surface water quality even when modern erosion and sediment control measures are used (Pond 2004). Mining through existing aquifers and pumping to dewater the mine could also affect groundwater flow in these drainages (National Research Council 1990, Schwartz and Crowe 1985, and Wilson and Hamilton 1978). However, it is not clear how a limited amount of morphological stream data could be used to restore streams affected by the loss of groundwater in the absence of adequate instream flow and groundwater data from streams 2002 and 2004.

Page 2.16-2.20: The use of the Rosgen stream classification system is useful to classify streams and stream reaches; however, there are problems with using classification data as a method to restore streams (Simon et al 2007 and Gillian 1996).

Page 2-20 paragraph 7. The flow of groundwater to streams 2002-2004, particularly during the winter, is one of the most critical factors in salmonid egg and overwintering survival (Baxter and McPhail 1999 and Douglas 2006). To successfully reconstruct a new stream that is equally as productive as the present stream 2003, it would be necessary to reconstruct a new shallow aquifer to provide the same amount of flow, reestablish seasonal flow patterns and duplicate the existing chemical composition of phreatic groundwater. This is important because: ground water in coal mine tailings often contains elevated levels of salts and metals such as zinc which is toxic to juvenile salmonids from 93 to 815 parts per billion, and; spawning salmonids use chemical cues to locate their natal streams (Chapman 1978 and Dittman and Quinn 1996). I have searched the scientific literature and haven’t found any instances where a new shallow aquifer has been recreated in a large drainage to support salmon spawning, or where premine ground water chemistry was duplicated.
It is not clear how the flow of groundwater to streams 2002-2004 could be determined by measuring surface water temperatures and noting what appear to be seeps and springs at a few sites. First, groundwater may enter the hyporheic zone at one point but not surface for some distance downstream. In order to accurately measure and map groundwater input, it would be necessary to measure temperatures in the streambed systematically at many locations over the entire drainage. There may be more effective means available than thermometers to identify and measure groundwater input into Chuitna drainage streams. A number of recent studies have used thermal infrared remote sensing to detect groundwater input into lakes and streams over a large area (Watershed Sciences 2007, Meijerink 1996, and Ackerman 2003).

Second, many species of salmonids select areas of groundwater input to spawn and overwinter (Bustard 1986, Baxter and McPhail 1999, Cunjack 1996 Swales et al 1986). Salmon eggs are deposited below the streambed and overwintering juvenile fish may move into streambed interstices in the hyporheic zone to escape ice and lethal low temperatures (Bjorn and Reiser 1991). Salmon eggs are deposited at some depth within the streambed. Large fish such as Chinook may dig as deep as 43 cm (17 inches) beneath the streambed and smaller fish 20-30 cm (8-11 inches). Phreatic groundwater at these depths would not be detected by surface water temperature measurements. In cold climates juvenile coho often select areas of groundwater upwelling to overwinter (Bustard 1986).

Stream habitat and abundance as CPUE page 3-11. The report indicates that: “Rosgen stream channel types will be used as the basis for river reconstruction after mining operations with each stream type encompassing a section of river with similar physical and biological attributes. Because of the importance of Rosgen stream channel types, statistical comparison of CPUE is based on Rosgen channel types.” The report should explain why Rosgen stream channel types are so important and why they will be used to reconstruct streams after mining.

The problem with simply using the Rosgen classification system to reconstruct 17.4 km of a salmon producing drainage is that it doesn’t take into consideration such things as water quality, surface water and groundwater seasonal flow patterns, stream temperature patterns, phreatic groundwater flow, and many other subtle factors that allow salmon to successfully complete their freshwater life cycle. Salmon in streams 2002-2004 are probably genetically adapted to the unique conditions in each of these streams and even small changes will likely result disrupt their life cycle.

*Habitat spawning surveys. Page 3-35 paragraph 1.* The range of temperatures reported at spawning redd locations (coho 7.32 to 11.36 degrees C, Chinook 11.60 to 15.56 degrees C, and pink 9.78 to 12.13 degrees C) is interesting. The lower temperatures at coho and pink redds could be an indication that coho and pink salmon are selecting sites with upwelling groundwater which in the summer would be colder than surface waters. Stream temperatures in the Cook Inlet basin tend to peak from May 15 to August 15 (Kyle and Brabets 2001). In 2006, Chuitna Chinook spawned from July to August, pinks
from mid-July to mid-August, and coho from August 15 to October 15 (Figure 4-1). However, it is not possible to determine from the data provided if salmon are selecting spawning areas with groundwater input, because water temperatures were taken at the surface of the redds instead of 8 to 17 inches into the stream bed where salmon eggs are deposited (Bjorn and Reiser 1991). Stream temperatures may also vary by several degrees daily and tend to be lower during pink and coho spawning.

**Adult Distribution page 4-14:** My experience is consistent with Oasis’s finding that beaver dams do not obstruct adult upstream migration. Because coho, chum and pink salmon runs tend to coincide with late summer and fall rains when beaver dams overflow, salmon and other species of fish are usually able to move upstream around or over the dams with little trouble. I have observed coho, sockeye, chum salmon, white fish, and Dolly Varden moving upstream past beaver dams during high water events. I also agree that given current coho numbers, ERT’s findings that “beaver dams were responsible for limiting adult coho access to far reaches of the drainages in 1982-1984” and that no coho were observed in stream 2003 in 1982, seem unusual. It could mean that there has been a major species shift from Chinook to coho salmon in stream 2003 or that coho’s were present in the system but earlier studies weren’t rigorous enough to detect them. Either scenario warrants additional research on coho and Chinook salmon abundance and life history. I discussed this with ADF&G research biologists and no major shift in relative coho and Chinook abundance was observed in other Cook Inlet streams from 1982 to 2009 (Hasbrouck 2009).

**Juvenile fish habitat considerations, pages 4.6-4.7.** Recent scientific studies have identified groundwater flow as a critical factor in the selection of adult salmonid spawning habitat, juvenile overwintering areas and the survival of eggs, fry and juvenile salmonids in cold climates (Leman 1993, Giannico and Hinch 2003, Malcolm et al 2004, Baxter and McPhail 1999, Lorenz and Filer 1989, and Douglas 2006). However, there is no discussion of groundwater flow as a habitat factor in the report. The 2006 study didn’t identify sources of groundwater or investigate the relationship between phreatic groundwater in the hyporheic zone and salmonid spawning and overwintering in streams 2002-2004. Figures 1 and 2 illustrate how groundwater enters streams. Mining coal to a depth of 300 feet will remove all the layers of sediment or lithological units of low permeability that confine the aquifers (confining units) and currently provide shallow groundwater to stream 2003 and possibly streams 2002 and 2004. To restore fish habitat in these streams after mining it, it would be necessary to restore these confining units and provide the same quality and quantity of groundwater.
Groundwater is critical because it maintains stream base flow and moderates water level fluctuations, particularly during the 5 to 6 months of winter when there is no liquid precipitation. It provides stable temperatures and thermal refugia for fish. It provides
water for riparian vegetation which controls bank strength and the rate of erosion (Douglas 2006). It also creates the hyporheic zone (Figure 3).

![Diagram of hyporheic zone](image)

Figure 3: Hyporheic Zone (Source: USGS Circular 1186)

The hyporheic zone is the region beneath and lateral to a streambed where there is mixing of shallow groundwater and surface water. It is an active ecotone between the surface stream and groundwater. Exchanges of water, nutrients, and organic matter occur in response to variations in discharge and bed topography and porosity. Upwelling subsurface water supplies stream organisms with nutrients and cool water in the summer and warm water in the winter. Downwelling stream water provides dissolved oxygen and
organic matter to microbes and invertebrates in the stream bottom (Boulton et al. 1998). Upwelling groundwater is vital because it protects salmonids and other cold water fishes from water temperatures that exceed their thermal tolerance in the summer (Hayes 2009). Groundwater provides overwintering habitat free of subsurface ice and protects fish eggs, larvae and juvenile fishes from freezing in the winter (Power et al. 1999).

Two types of groundwater influence streams: Hyporheic groundwater and phreatic groundwater (Poole and Berman 2001). Hyporheic groundwater is from the alluvial material which underlies the streambed. It travels downstream along localized pathways before emerging further downstream. Phreatic groundwater comes from the catchment’s aquifer and feeds a stream by entering the bottom of the alluvial material and mixing with the hyporheic groundwater (USGS 2006). Groundwater from the phreatic aquifer influences stream temperature when it enters the stream. The two-way exchange between the alluvial aquifer and the stream channel is perhaps the most important stream temperature buffer (Douglas 2006).

The hyporheic zone is an area of intense biochemical activity. Biogeochemical processes within the upper few centimeters of sediments have a profound effect on the chemistry of groundwater and surface water that mix in that area. Biogeochemical process is the partitioning and cycling of chemical elements and compounds between the living and non-living parts of a stream. The highly interactive nature of physical, chemical and biological processes in the hyporheic zone play a central role in the functioning of stream ecosystems (Malcolm et al. 2003).

Streams can be classified as gaining, losing, or disconnected. Gaining streams gain surface flow from inflowing groundwater and losing streams lose flow through the streambed to the groundwater. Disconnected streams are streams where there is an unsaturated layer of air between the stream and groundwater. Streams can be both gaining and losing.
Figure 4: A. Gaining stream, A. Losing stream and C. Disconnected stream  
(Source USGS Circular 1186)

Streams 2002-2004 appear to be gaining streams but could have sections which lose water to a deeper aquifer. However, it does not appear that PacRim or its contractors has collected enough data to make a stream segment by segment determination. Deep mining through the existing aquifers and pumping to draw down the aquifers and dewater the pit would likely lower the water table substantially. As a result, Stream 2003 would likely become a disconnected stream and lose water (Figures 4A, 4C, and 5). It is possible that streams 2002 and 2004 could also be affected by the drawdown of the water table.
Monitoring and testing of groundwater in reclaimed strip coal mines indicate that groundwater is stored in and flows through large voids or conduits in spoil. However, these voids are not always connected across a mine site (Hawkins 1998 and Hawkins and Aljoe 1992). Because groundwater does not flow through coal mine spoils as it would through unconsolidated alluvium it would be very difficult to design and restore phreatic groundwater flow to stream 2003 or insure that groundwater flow to streams 2002 and 2004 would be maintained.

4.7. Human Use page 4.34 Commercial, personal and subsistence harvest: Although the reported average commercial harvest of approximately 33,000 sockeye and 33,000 coho from the Beluga and Tyonek Districts (which includes fish from the Chuitna River) may not seem large when compared to other fishing districts in Cook Inlet, these are healthy runs which can continue in perpetuity as long as the habitat is intact. To put this into perspective the sockeye harvest in these districts is almost twice the 2008 Canadian commercial harvest of 16,000 sockeye from the Frazer River (Pacific Salmon Commission 2008). The Frazer River was once one of the largest sockeye salmon producing systems in the world, but since the 1990’s the runs have declined precipitously. Some Frazer River coho and steelhead stock are so depressed they have been classified as endangered. Fisheries and Oceans Canada (2008) attributes the decline to watershed development including mining, agriculture, logging and global warming. Even though the Canadian government has attempted to arrest the decline by spending millions of dollars on the same types of habitat restoration and enhancement proposed for the Chuitna Coal Mine, these efforts have been largely unsuccessful.

Summary:

1. The report does not explain how one year of CPUE data from minnow trapping can be used to determine the impact of strip mining on stream 2003 or how it will be used in stream restoration. The assumptions, limitations and problems with using minnow traps are not presented or discussed in the report. CPUE does not provide an estimate of the population size of each species of fish which is needed to assess impacts and restoration success. Juvenile salmon populations and CPUE may change substantially from year to year and from stream to stream. For
example, over a 17-year period the estimated juvenile coho population in the Kenai River ranged from 400,000 to 1,200,000, a change of over 300% (Massengill 2009).

2. Aerial and foot adult escapement surveys do not provide accurate estimates of escapement levels, especially in small streams. A weir or sonar counter is needed to enumerate adult escapement into the Chuitna River and into streams 2002-2004. Because of substantial annual variations in run size, a minimum of 5 to ten years of continuous escapement data is needed.

3. A comprehensive understanding of stream flow and groundwater flow into streams 2002-2004 is necessary to determine the instream flow needs of fish and other aquatic life and to assess impacts of strip mining and to restore watersheds impacted by mining. However, no comprehensive instream flow study and no study of the input of shallow groundwater by sub-basin have been conducted. To account for seasonal and annual fluctuations in groundwater, a minimum of 5 to 10 of years of data are needed (Rice 2009, Zhou et al 2004, and Mouw 2009).

C. Chuitna Coal: 2007 Aquatic Biology Studies Program

1. Introduction

Page 1: The purpose of the 2007 Oasis aquatic biology studies program was to supplement and enhance the baseline information gathered in 2006. The purpose of the 2006 study was to determine resources and habitats in the Chuitna drainage that could be affected by the project, including streams 2002, 2003, 2004, Chuit and Three Mile Creeks and the mainstem Chuitna River.

Analysis and Comments:

2.1 Methods:

2.1.1 page 2.1 paragraph 2. The selection of minnow trapping sites based on what the researchers believed to be good habitat (e.g. good cover and low water velocities) may have biased the results. Traps should have been placed using a randomly generated sampling strategy in all types of habitat and the catch rates should have been used to identify preferred coho habitat in streams 2002-2004. Variations in water levels and water velocities at the trap sites over the sampling period would also affect the catch rate. High water levels and increased water velocities would displace coho from trap sites to slower waters. High water velocities could result in a narrower cone of dispersal, carry the scent further downstream, and make it more difficult for fish to swim upstream to the trap. Lower water levels and velocities would have the opposite effect. Catches from traps placed in shallow and faster water would have helped support the researcher’s concept of good coho rearing habitat.
Minnow trapping occurred at the same sites in 2006 and 2003, but the report did not indicate whether or not there had been any changes in the stream channel (i.e. cover, water velocities, or substrate) at those sites, which could have affected the catch rate.

2.1.1 Paragraph 3 page 2.2. Why were all of the juvenile Coho from streams 2002-2004 and the Chuitna pooled for the length frequency analysis? A separate analysis could have shown if there are morphological differences (i.e. size, condition etc.) between coho stocks in these streams. Morphological differences, which may be the result of genetic isolation, have been documented in scientific studies of coho stocks in nearby tributaries of small coastal watersheds (Bailey and Irvine 1991). This is important because if observed differences were the result of genetic isolation and adaptation to the unique conditions in these streams, it would make the task of successfully restoring stream 2003 fish populations much more difficult.

*Figure 2.1.1.* It could be problematic that all of the minnow trapping locations were located at or below the road crossing. The effects of road construction include short term elimination of benthic life and fish population for some distance below the crossing site due to siltation and turbidity, as well as obstruction of adult and juvenile upstream migration due to poorly installed and maintained culverts, floods etc. (Barton 2006 and Moore et al 1999).

*Figure 2.1.2.* Why wasn’t there any winter trapping in streams 2002 and 2004 to identify and characterize overwintering habitat? Suitable overwintering habitat associated with the input of groundwater is believed to be a critical factor in freshwater salmonid survival in cold climates (Fisheries and Oceans Canada 2009, Mouw 2005, and Baxter and McPhail 1999). Streams 2002 and 2004 and their fish populations are almost certainly going to be adversely affected by changes in surface and groundwater temperature and flow resulting from deep mining in their watersheds. It is possible that these streams could change from gaining streams to losing streams due to groundwater pumping to dewater the mine (USGS 2008 and Hancock 2002).

2.1.1 Page 2.6 Paragraph 1. The statement that “CPUE was calculated by dividing the catch by the number of hours fished and multiplied by 24 hours for a nominalized trap catch for 24 hours” needs some clarification since the same paragraph indicates that the traps were fished for 24 hours! Further, the use of the CPUE’s from these traps needs to be qualified because in areas of high population density, catches of juvenile salmonids probably reach a peak after 1-2 hours while catches in areas of lower density may continue to increase over 24 hours (Swales 2008). Because of this phenomenon, the relative densities of coho populations estimated from 24 hour trap soaks may be too low for high density areas and too high for low density areas.

3. Results and Discussion:

3.1.1.1. Fisheries Resources: page 3.1 Paragraph 2. The explanation for the use of percent relative composition (i.e. percentage composition provided a way to discuss the relative numbers of species captured in minnow traps and make inferences on the
communities which reside in those streams) instead of CPUE is unclear. Why not use both? CPUE gives the reader an idea of the relative population densities by stream. A comparison of CPUE by species by year can also provide an indication of changes in population numbers and community composition (i.e. a 50% decline in CPUE might indicate a change in population numbers). CPUE is also commonly used in fisheries studies for that purpose.

Page 3.1 paragraph 3. It is generally believed that pink salmon fry in coastal streams do not feed in fresh water but migrate directly out to marine waters. In freshwater, chum salmon fry feed on insect larvae for some time before outmigration. It is not likely that they would be captured in smolt traps baited with salmon eggs. Also, age zero fry of all species and possibly some age 1 fry are small enough to swim through the mesh used in minnow traps. This means that these species and age groups may have been present but underrepresented in the catches.

Page 3.1 Coho salmon: The use of percentages of catch by species in the catch does not seem to be that useful for purposes of environmental impacts assessment, permitting and mitigation. The actual number of each species captured would have been more useful. For example, 88% of a catch of a million fish (880,000) is a lot different than 88% of a thousand fish (888). It is unclear whether the percentage figures (63-88% of the fish population) are for coho fry alone or if they include spawning adults.

Page 3.3 Paragraph 3 Sticklebacks: The large increase in stickleback numbers in the Chuitna and Threemile Creek could be explained by the fact that there are anadromous stocks of sticklebacks in Cook Inlet and they enter streams in large numbers in some years.

3.1.3.2 Comparing Rosgen Stream Types Within Study Streams: Page 3.15 paragraph 2: There are many different types of Rosgen B, E and C channels based in part on slope. The statement that “Rosgen type B channels typically exhibit the highest gradient and current velocities compared to C and E channel types” is accurate only for B1a-B6a channel types (Rosgen 1994 and 1996). B1-B6 and B1c-B6c have the same slopes as Type E channels and C 1b-C6b channels. The authors should specify what types of B channels they are reporting on, especially if this information is going to be used in developing mitigation and reconstructing stream channels.

Page 3.16, paragraph 1: The speculation that Rosgen type C channels supported the highest concentrations of spawning adult coho and also had the highest CPUE of all channel types, and that this might be related to nutrients provided by adult salmon eggs and carcasses is important. It is important because mining will eliminate these stream channels and the anadromous fish stocks which spawn in them.
There is a large body of scientific literature showing that Pacific salmon are the major vehicle transporting marine nutrients across ecosystem boundaries from marine to freshwater and terrestrial ecosystems. Nutrients from salmon eggs and carcasses play a major role in the productivity of both freshwater and riparian ecosystems and in perpetuating future salmon runs. Most fisheries scientists and fisheries managers have concluded that stream ecosystem health benefits from having the largest number of spawning salmon possible (WDFW 1997), which in turn produces a large number of carcasses. The eggs and carcasses from these spawning salmon provide an essential source of food for rearing salmon and other fishes which concentrate in these areas. Nutrients from decaying carcasses also provide food and nutrients for insects such as chironomids which are the major food source for salmonids during the rest of the growing season. Bilby et al (1996 and 1998) found that benthic algae, invertebrates and fish in salmon streams were significantly enriched with both marine carbon and nitrogen. The average contribution of marine nitrogen ranged from 11% for invertebrate predators to 31% for juvenile Coho. The highest percentage of marine nitrogen was 46% for adult cutthroat trout and 61% for age 1 plus steelhead. The same researchers also found that the growth rate of juvenile coho doubled after adults spawned in the stream, whereas in a nearby stream without spawning salmon juvenile steelhead showed no increase in growth rate during the same time period. This phenomenon is so important that fisheries scientists recommend that escapement goals should be designed to produce “nutrient capital” within watershed that will help support the next generation of fish.

During mining, salmon will be excluded from the middle and upper portions of Stream 2003 where most spawning and rearing occurs for a long period of time. The “nutrient capital” built up over hundreds of years would be lost when the drainage is destroyed. Diminishing or eliminating salmon production (i.e. eggs and carcasses) from a stream due to natural or anthropomorphic causes such as strip mining may be self-perpetuating. Without necessary nutrients from salmon eggs and carcasses remaining downstream, stream 2003 stocks are likely to decline further. A restored stream drainage without nutrients from salmon carcasses is not likely to be very productive (Bilby et al 1996 and Larkin and Slaney 1997). The concurrent loss of most of the wetlands, which are the other major source of stream nutrients in the stream 2003 drainage, will further reduce stream productivity (Hood et al 2008, Meyer et al 2003, and Nagorski et al 2007). Significant loss of stream productivity from premining conditions has been documented in studies of streams in reclaimed stripmines. Matter and Ney (1981) found that 5 to 7 years after reclamation, “benthic invertebrate and fish populations were significantly lower in abundance in the reclaimed mine streams than in the reference stream and showed less taxonomic richness and stability. Biota of reclaimed streams were similar in these respects to the biota of unreclaimed mine streams.”

Page 3.16 Paragraph 3. The authors suggest that with some distinctions, data from streams 2004 and 2002 may be similar to stream 2003, and as “mine development progresses impacting stream 2003, streams 2002 and 2004 can be used for comparative purposes to stream 2003.” With enough years of data to determine fluctuations in the abundance and composition of fish populations with statistical confidence, streams 2002
and 2004 might provide some general comparison with stream 2003. However, it seems likely that stream 2004 and possibly stream 2002 may be also impacted by changes in surface and groundwater flow and water quality from mining in their watersheds. If so, these impacts would negate any objective comparisons.

3.1.3.3 Longitudinal Comparison of CPUE between Streams:

3.1.3.4 Study Streams Coho Salmon: page 3-19 paragraph 3. The admonition that “just because C channel produces higher CPUE than other stream channel types it should not suggest that the length of stream 2003 be rebuilt as a C channel in reclamation planning and construction” is good advice. Reconstructing a stream channel to approximate any of the physical characteristics of Rosgen stream types (i.e. entrenchment ratio, width depth ratio, sinuosity, slope etc.) does not provide any assurance that the new waterway would provide the key characteristics of productive salmonid habitat, such as hyporheic flows, groundwater upwelling, nutrient input from adult salmon, and the 2000 acres of wetlands in this drainage. Although, there are hundreds of thousands of streams in Alaska with Rosgen B, C, and E channels, less than 20,000 are have been found to support spawning, rearing or migrating salmonids and a fraction of those have the unique conditions which provide spawning habitat for coho, or Chinook salmon.

Although there are examples of stream channels that have been reconstructed, rehabilitated or relocated in Alaska, all of these projects have entailed restoration of stream banks, movement of short sections stream channels within an existing flood plain or relocation of a stream to an old stream channel. (i.e Moose Creek). I was also unable to find any pre- and post-construction quantitative scientific studies documenting the biological and physical effects of these projects on fish populations.

3.1.3.1. page 3-36, paragraph 2. The statement that “juvenile Chinook may emerge from the gravel to migrate to sea at age zero: therefore they may not be present during the winter during our trapping” is not consistent with the increased winter Chinook catch rates shown in Table 3.1-11. A large percentage of age zero Chinook do smolt in some systems, but all studies to date indicate that Cook Inlet Chinook smolt at age 1 (Hasbrouck 2009, Kerkvliet 2009). It is important to establish whether the Chuitna Chinook smolt out migration at age 1 or age 0 for impact assessment, permitting and mitigation purposes.

The authors could be correct that pink and chum fry were not free swimming during the time the minnow traps were in the streams; however, in my experience pink, sockeye and chum salmon fry are usually not caught in minnow traps. Often they are so small that they can swim through the mesh in the minnow traps, and they may not be attracted to the salmon egg bait.

Table 3.1-12 page 3-37. There appears to be something wrong with the average length column for table 3.1.12. Aside from the fact that the column has no unit of measurement, e.g. millimeters or centimeters, the average lengths given do not seem to be correct. For
example, it seems unlikely that a juvenile coho salmon would ever be as small as 8mm or .323 inches, or that a fish that small could be captured.

**3.1.3.12 Electrofishing.** Was electrofishing conducted at the same time as trapping so that the same fish populations were sampled? If not, it would not be safe to conclude that the minnow traps were capturing all of the species and age groups present.

**3.1.4.1 Spawning surveys page 3-40.** Foot and aerial surveys usually significantly underestimate the number of spawning salmon present in a stream (Jones et al 1998). To accurately enumerate the number of salmon spawning in Stream 2003, a weir or sonar counter should have been installed and operated for 5 or more years. Accurate weir or sonar counts of adult salmon from the mainstem Chuitna and streams 2002 and 2004 are also needed.

Page 3-81, paragraph 3. This paragraph states that the majority of the data necessary to reconstruct/design stream 2003 has been collected and all that remains is to establish exact channel positions (plan form) and compile streambed elevations through the mine. It further states that “Data collected to date has been sufficient to characterize existing reference conditions, and to provide evidence of restoration feasibility.” Oasis believes that they have almost all of the data and the expertise to reestablish a functioning salmon spawning stream after all of the existing vegetation has been removed, the entire upper stream 2003 watershed is excavated, the underlying substrate excavated to a considerable depth, and the surface hydrology and the existing shallow aquifer completely disrupted.

I disagree that PacRim has collected all the data necessary to reclaim stream 2003 and its drainage. For example, no data is provided on present shallow groundwater flow or the techniques that could be used to successfully restore essential groundwater flow to a reconstructed stream 2003. PacRim has not studied or provided any data on the role of marine nutrients from salmon carcasses or nutrients from wetlands in the productivity of the stream 2003 drainage. There is no explanation of how they would restore the thousands of acres of wetlands that would be destroyed by mining. Most importantly, they haven’t provided any examples from the scientific literature of successful restoration of the type and scale they are proposing.

Although I have over 25 years of experience in analyzing and permitting projects affecting fish habitat, including large and small mines in Alaska, I am not aware of any instance where a salmon spawning and rearing drainage has been completely altered in the manner proposed for the Chunitna coal mine and then restored to its original productive state. There have been cases where small sections of previously mined stream channels have been altered to provide more productive salmon habitat and by chance has provided spawning habitat, such as the Forest Service’s restoration efforts on the Resurrection River near Hope, Alaska, but no restorations of the type and scale proposed for stream 2003.
After mining the entire stream 2003 drainage and portions of stream 2002 and 2004, the drainages will consist of highly erodeable mine spoils, and water quality, including silt and turbidity, will be an issue that will affect the success of attempts to restore salmon habitat. The recovery of a stream affected by coal strip mining was monitored after mine closure by researchers from USGS (Collier 1963). The study found that mining significantly changed the chemical quality of the groundwater and surface waters, increased the sediment yield, and adversely affected the aquatic life of the stream. Even though the mined area only included 6.4% of the drainage basin, it contributed 96% of the sheet erosion. The stream affected by mining discharged 2,800 tons of sediment per square mile, whereas the control stream in an adjacent unmined drainage discharged only 49 tons per square mile during the same period. Clearing and developing land for mines increases sediment input into streams, lakes and rivers (Environmental Protection Agency, 1999, 2006 and 2008). Glancy (1973), who studied sediment loads in tributaries to Lake Tahoe, estimated that sediment yields from undeveloped areas ranged from 19 to 420 tons per square mile, whereas sediment yields from developed areas ranged from 700 to 5000 tons per square mile.

Because much or all of the vegetation in the mined areas will be removed, it seems likely that stream and groundwater temperatures will increase in summer and decrease in winter to the detriment of spawning and rearing salmonids (Beschta and Taylor 2007, Cunjack 1996, Feller 1982, and Curry et al 2002). There is no mention of this issue in the report, or of how restoration efforts will address detrimental changes in water temperature until mature vegetation is reestablished.

3.8.1 Landscape scale investigations page 3-102 paragraph 2. Upwelling groundwater and adequate instream flow is essential to successful salmonid spawning and juvenile overwintering survival in Southcentral Alaska (Alfredsen and Tesaker 2002, Baxter and Hauer, 2000, Malcolm et al 2004 and Mouw 2005). In section 3-81, Oasis purports to have almost all of the data necessary to restore Stream 2003 to productive salmon habitat. Yet, in this paragraph Oasis indicates that they don’t have the detailed information on groundwater location, flow rate, temperature etc necessary to restore stream 2003: “The predominantly glacial alluvium lacked distinct surface nick points in the geological stratigraphy to force hydraulic pressure upward at longitudinal breaks.” Also: “Landscape features were not available in steam 2003 that would serve as predictors of hydraulic exchange, and spatial heterogeneity, suggested areas of local hydraulic exchange.”

Landscape Scale Investigations Page 3-106, paragraph 2. Although most of the findings in paragraph 2 are consistent with other studies of hyporheic exchange in salmonid spawning areas, the finding that “most adult salmon selected downwelling zones for spawning” may not tell the entire story about the dynamics of these spawning areas. Other researchers have found that in areas where freezing can destroy salmon embryos, salmon seem to favor sites with upwelling groundwater, which will be warmer in winter (Quinn 2005). This behavior is documented in sockeye, coho, Chinook and chum salmon in Alaska (Quinn 2005 and USFWS 2009). A comprehensive study of redd site selection by bull trout (Salvelinus confluentus) found that they selected stream reaches for
spawning that were strongly influenced by upwelling groundwater but located redds in transitional bed forms that processed strong localized downwelling and high intergravel flows (Baxter and Hauer 2000). Similarly Malcolm et al (2004) found that Atlantic salmon (Salmo salar) selected areas of complex groundwater-surface water interactions and that during critical freezing or low flow conditions hyporheic conditions were dominated by groundwater, whereas surface water dominated during high flow conditions. Additional research is needed on the influence of groundwater on redd site selection for all species of salmonids in streams 2002-2004.

Page 3-113 paragraph 1. Oasis makes the point that there are significant differences between streams 2002, 2004 and 2003, and that these differences should be taken into consideration when comparing these streams to stream 2003 during mining. This conclusion is correct. The physical and biological differences between these streams and the possibility that these streams may also be affected by mining raises serious questions about using these streams as controls or templates for stream 2003 restoration. The type of comparison which might be appropriate is this: If there were normal populations of adult and juvenile salmon in streams 2002 and 2004 and few or no salmon in the restored sections of stream 2003, it would likely indicate that the restoration efforts were not successful. However, if there were 10 or more years of comprehensive pre-mining physical and biological baseline for stream 2003 to be used as a model for reconstruction, such a comparison would not be necessary.

Page 3-113: Velocity paragraph 2; Velocity: Oasis reports that “water velocity and currents could have significant effect on (minnow trap) catch rates (Bjorn and Reiser, 1991) and both influence habitat use by juvenile fish.” This statement is correct. However, catch rates can also be affected by water temperature (too high or low), turbidity, and time of day. These factors were not reported on or discussed in the report (Bjorn and Reiser, 1991).

Oasis measured water velocities at each trap site and found that “Velocities ranged from 2.0 feet per second to 0 feet per second with 50% of the sets having velocities less than .5fps and 90% of the velocities less than 1fps.” They reported that “juvenile trout, salmon and char (40 to 180 mm in length) usually occupy sites with velocities up to 1.3 fps (Bjorn and Reiser 1991) and juvenile coho salmon prefer pools with velocities less than .7 fps (Bisson et al 1988).” They concluded that “the preferred velocities are close to or below over 90% of typical trap site velocities, therefore velocity was not a limiting factor for catching fish at individual trap sets.”

I checked Table 4.10 in Bjorn and Reiser (1991) for depths and velocities at sites used by salmonids in streams. The velocities reported for age 0 coho salmon in natural habitat ranged from .16 fps to .98 fps and for age 1 coho from .59 to .98 fps. This is lower than the range of preferred velocities reported by Oasis and would indicate that the percentage of time that water velocities at the trap sites exceeded preferred water velocities was greater than estimated. Preferred velocities for age 0 Chinook salmon are similar to juvenile coho salmon (Bjorn and Reiser 1991). Water velocities well above preferred velocities would likely reduce catch rates at times, particularly at high flows when
turbidity would also increase. At high flows, juvenile salmonids and other fishes would move to areas with lower velocities. Fluctuating catch rates along with the other limitations of minnow traps as a scientific sampling tool add uncertainty to the data and limit the value of the minnow trap data to compare catch rates over time and between streams.

Page 3-115. Depth. I am not sure that it is scientifically sound to conclude that “Given that 90% of trap sites were in water less than 3 feet deep, combined with the belief that preferred water depths will be readily subjugated to access to food, and security to predators, and that traps were set in a minimum depth so that the trap entrances were submerged, it is not likely that water depth limited or biased catch rates.”

I could not find any source in the literature cited section for the citation that “Juvenile coho salmon show a maximum preference for depths of 3.3 feet (Beecher et al 2002).” It is also not clear from the Oasis report if this means that juvenile Coho salmon prefer depths of 3.3 feet or that this is the maximum depth that they are found at. The article cited in the North American Journal of Fisheries Management actually stated that “Juvenile coho showed maximum preference for depths of 76-100 cm (2.49 feet-3.3 feet) and velocities of 3-6cm/s (.098-.196 f/s)” (Beecher et al 2002). Velocities of .098-.196 f/s indicate very slow moving water that would typically be found in pools or near stream banks! Other researchers have reported that at water velocities of 0.30 to 0.98 f/s, juvenile coho salmon preferred shallower water (i.e. 0.98-2.2 feet) (Nickelson and Reisenbichler 1977). It appears that there is a relationship between coho presence, water depth and water velocities that is not accounted for in the Oasis conclusions. If coho moved from a trap site in response to fluctuating water levels or velocities, which occurred a number of times over the study, it would affect catch rates. Because Oasis apparently did not constantly monitor water levels or velocities at trap sites there is no way to compare catch rates to these parameters to see what effect they may have had.

The statement that juvenile Chinook salmon have been found in depths ranging from .5 to 4.5 feet (Bjorn and Reiser, 1991) is not meaningful by itself. I have captured juvenile Chinook in dip nets in a few inches of water and in inclined plane traps in 8 feet of water. This does not mean that those depths are preferred habitat for juvenile Chinook salmon, or that minnow traps placed in those areas would provide an unbiased index of abundance. The 5 studies cited in Table 4.10 in Bjorn and Reiser (1991) indicate that most age 0 Chinook fry were found in water depths of .5 feet to 2.0 feet of water at water velocities of 0.20 to 0.98 f/s. It seems likely that when water depths or velocities exceeded those depths and velocities, catches would be reduced to some degree, affecting CPUE.

Another factor that was not discussed, but that could have negatively influenced juvenile Chinook catches, is that juvenile coho could have displaced juvenile Chinook from areas with minnow traps because the traps contained a favored food source (i.e. salmon eggs). Coho fry are aggressive and territorial soon after emergence, and they establish intraspecific dominance hierarchies (Mason and Chapman (1965). Where coho and
Chinook fry occurred together in streams, the coho were socially dominant, defending territory accessible to incoming food (Stein et al. 1972).

**Page 3-116. Temperature.** The Oasis data does not appear to support the conclusion that “since temperatures show a consistent pattern across drainages, temperature is not considered to significantly bias CPUE between drainage. Rather catch rates changed throughout the season, equally between drainages.” A comparison of Figures 3.1.5-3.1.5 coho salmon CPUE and the accompanying tables by month and location for streams 2002-2004 indicates that CPUE did not change “equally” by stream over the season. The CPUE curves between streams and within streams between May and September appear to be significantly different. For example, as depicted in Figure 3.9.4, catch rates in streams 2002 and 2004 declined in September as water temperatures declined. However, 2007 catch rates for all sections of Stream 2003 actually increased significantly in September! This suggests that either the temperature measurements are incorrect or catch rates were influenced by some other factor than temperature.

Another factor that was not investigated but could have reduced catches of Chinook and rainbow trout is that juvenile salmonids that live in streams are sometimes nocturnal and may not feed during the day (Bradford and Higgins 2001). Little is known about diel activity of salmonid movement patterns in Alaska, however, researchers in British Colombia found nocturnal diel activity patterns in Chinook salmon and rainbow trout in areas of high flow in the Bridge River. Parr and older fish were more nocturnal in summer than fry, and all fish were nocturnal during the winter. They concluded that habitat-driven variations in activity patterns will likely affect the processes that regulate these populations and could make the prediction of the effects of ecosystem manipulation such as changes in flow very difficult.

**Summary:**
The problems and limitations of using minnow traps and other types of passive fishing gear in scientific studies are well-known (Hubert 1996). Gear selectivity leads to misrepresentation of certain types (e.g., particular size or species) of fish relative to their actual abundance in the environment (Hubert 1996 and Breen and Ruetz 2006). All passive fishing devices are selective for certain species, sizes or sexes of animals.

There is so much variation in CPUE within and between streams 2002-2004, and between years, that it is difficult to imagine how this data could be used to monitor mining-related changes in stream 2003. If a consistent pattern exists, it would take many more years of data collection to determine whether such a pattern exists and what it is.

It is not clear how the emphasis on CPUE and percent relative composition fits into the regulatory requirements for avoidance, mitigation and replacement. An estimate of the actual numbers of adult and juvenile salmonids produced by streams 2002-2004 from sonar and weir counts would be more useful to assessing impacts and developing mitigation and monitoring. The data from minnow trapping is not likely to produce a population estimate with any degree of confidence. Because of the natural variation in
adult and juvenile salmonid populations in Cook Inlet, 5 to 10 years of sonar or weir data would be necessary to provide estimates with any degree of confidence.

It appears that the objective of collecting morphological stream data may be to meet permitting requirements by replacing the stream miles of Rosgen type B, C, and E that will be destroyed with reconstructed habitat that meets the characteristics of B, C, and E habitat. It is not clear how merely duplicating the general physical characteristics of stream 2003 can be considered successful restoration. For example, this is no discussion of how the flow of hyporheic groundwater to stream 2003 would be restored. One of the most critical factors in stream restoration appears to be the input of groundwater to the hyporheic zone. Ground water contributes cooler water to the instream flow during the summer, and warmer water which comprises the total flow during the winter months. This flow, which is near the mean annual air temperature, controls the development rate of salmon eggs and allows juvenile salmonids to successfully overwinter.

D. Wetland Functional Assessment (HDR Alaska, Inc., March 5, 2008);

HDR’s report is a supplement to the Baseline Report for Vegetation and Wetlands (HDR Alaska 2007b). The baseline report detailed how wetlands were identified and mapped. This report addresses the assessment of functions performed by wetlands identified in the baseline study.

Analysis and Comments:
This report provides important information on the functions provided by the 3,921 acres of wetlands that will be destroyed by strip mining. HDR lists 6 functions those wetlands provide, including: wildlife habitat, stream flow moderation, shoreline stabilization, groundwater discharge, groundwater recharge, and carbon export/food chain support. Two additional wetlands functions that are not identified in the assessment are water quality maintenance and fish habitat. Wetlands filter out pollutants and trap silt and sediment that would otherwise enter fisheries habitat. This becomes increasingly important in disturbed areas such as a strip mine. Wetlands that are connected to streams can provide important fish habitat, particularly for juvenile coho salmon.

Results: Page 13. HDR estimates that there are 4,000 acres of wetlands in the Chuitna Coal Mine Mapping area, or 43% of the mine area. They estimate that the acreage of wetlands within the mine area providing the following important functions are: Stream flow moderation, 340 acres; groundwater discharge, 1,646 acres; groundwater recharge, 24 acres; carbon export/food chain support, 2,120 acres; and total functional wetlands acreage by component, 3,023 acres (HDR 2008).

According to HDR, the total acreage of wetlands providing groundwater discharge in the project area is 2,171, and the total acreage of wetlands providing carbon export/food chain support is 4,174.
Page 22: Wetlands to be destroyed by strip mining currently provide the following functions in the Chuitna Coal Mine Area: 9% of wetlands providing stream flow moderation; 1,646 acres or 42% of the wetlands providing groundwater discharge; 1% of the wetlands providing groundwater recharge; and 56.5% of the wetlands providing carbon export/food chain support to streams 2002-2004.

Page 24: Total functional wetlands acreage in the Chuitna Coal Mine Area: 3,023 acres, or 77% of the total of 3,921 acres of wetlands in the mine area, provide essential functions for streams 2002, 2003, and 2004.

Summary:
The productivity of a salmon stream is based on marine derived nutrients (MDN) from salmon carcasses and the flow of organic matter, nutrients, and the consistent flow of high quality groundwater and surface water from its drainage basin (Piccolo et al 2009, Mathisen et al 1998, and Schlosser 1991). Wetlands have been identified as a major terrestrial contributor of organic matter and nutrients to salmon streams (Hood et al 2008, Pess et al 2002, and Nagorski et al 2007). All of the wetlands, which currently comprise 43% of the proposed mine area and currently provide groundwater discharge, groundwater recharge, and carbon export/food chain support to streams 2002, 2003, and 2004, would be destroyed by mining. There is no plan to replace these wetlands, and it may not be technically or economically feasible to construct thousands of acres of replacement wetlands. At the same time, both the reservoir of MDN within the mine area and the input of MND from salmon carcasses will be lost when the stream 2003 channel and riparian area is mined. Even if stream 2003 could be reconstructed, the loss of both of the major sources of stream productivity (i.e. marine derived nutrients and wetlands) would make it very difficult to restore it to its former level of productivity. The loss of a portion of the wetlands in the streams 2002 and 2004 drainages will also affect the productivity of these systems.


I. Introduction: Oasis’s stated objective for the Oasis Environmental Inc. Winter Freshwater Fish Habitat Baseline Report, January 2009, was to determine the location, longitudinal movement and habitat use of overwintering fish (primarily juvenile coho salmon and small resident Dolly Varden) within randomly selected segments of stream 2003 within the proposed Chuitna Coal Mine project area during the winter of 2007/2008. The purpose was to satisfy permitting requirements and to obtain an understanding of winter habitat use to assess and mitigate habitat loss and biological impacts of the proposed project.

Analysis and Comments:
II. Methods:
Section 2.3.1. Page 15: Oasis reports that the estimated tagging mortality for juvenile coho salmon was 4% and 0.7% for Dolly Varden. Given the description in Section 2.3.2 of the difficulties encountered in capturing, holding and tagging fish under very adverse conditions (e.g. fish freezing to the tagging boards), it is surprising the mortality was so low. No information was provided in the report on the number of fish that died before being released. Although the process of handling and injection of foreign material into very small fish always entails a risk of infection or physical injury, no estimate of long term mortality after release into stream 2003 was provided. A Peterson mark and recapture population estimate is based on the ratio of the total number of tagged fish released to the number of tagged fish recaptured when the population is sampled. Increased post-release mortality of tagged fish would result in an overestimate of population size.

Section 2.3.1 Page 15. It would be very useful to be able to compare the total number of fish captured during both the tagging and recapture operations. Table 4.1 indicates that a total of 2,198 coho were recaptured, of which 82 were tagged. The results section indicates that a total of 2,032 Dolly Varden were captured and 125 were tagged, but no similar number was provided for coho. It seems unlikely that all coho captured were tagged.

Section 2.3.3. Page 20. Although underwater video recording has the potential to provide some information on the presence and absence of Dolly Varden and coho in riffles and fast run habitat under the difficult conditions the researchers encountered, its use raises some questions. The disturbance from drilling holes in the ice and artificial light seems likely to displace overwintering fish from the area of disturbance. In the 1970’s, I was involved in an extensive research project which involved the use of underwater video recording. My experience was that fish rapidly left the area when the camera and light system was introduced. Other researchers have reported that the lighting needed for underwater video cameras caused similar avoidance problems (Rand and Logerwell, 2009). Additionally, while bait can be used to attract fish from downstream to the area of the video camera, there is no way to determine if the fish are coming from shallow riffle habitat rather than deep pools or other habitats downstream.

III. Results:

Page 26: The statement that “variations in the number of fish (tagged per site) generally reflected the abundance of fish that were present in each particular stream segment at the time of trapping” is unclear. Does this mean that Oasis had some way of determining the total number of fish in each stream segment, which seems unlikely; or does it mean that they were not able to capture 200 fish in all sections because of low catch rates in some sections? This should be clarified.

Section 3.2 Winter Movement. Page 27. The finding that tagged overwintering Dolly Varden and Coho tended to remain in the same stream sections during the winter is useful. However, there is a possibility that untagged fish from the mainstem Chuitna or other stream sections could have moved into Stream 2003 after tagging ended on October 27. The recapture of tagged fish would not have documented these movements. It is
possible that some previous study addressed this issue, but this report did not exclude that possibility.

Section 3.3 Underwater Video Recording Page 28: See previous comments on Section 2.3.3. The report indicates that video recordings were also made in streams 2002 and 2004. No reason was given for looking at these streams and it isn’t clear whether or not fish were observed.

IV. Discussion:

Page 31 paragraph 1: I agree that information on the behavior and winter habitat preferences of stream fishes in Alaska is very limited. Because juvenile fish of the same species in Alaska are likely adapted genetically to very severe winter conditions (thick ice, very low temperatures, low oxygen levels, longer winters, different stream flow regimes etc.), it is not clear how much information from southern populations, including British Colombia, is applicable to stream 2003 without verification through independent research (Olsen et al 2003). Because detailed information on the life history and winter habitat preferences of Chuitna drainages fishes is essential to assessment of impacts, potential mitigation of impacts and successful restoration of stream 2003, a great deal of additional research in this area is needed (see conclusions section).

Page 31 paragraph 2: The explanation given for why overwintering juvenile coho salmon in stream 2002 were not captured in large numbers in beaver ponds in the stream 2003 drainage, whereas in more southerly coho populations beaver dams are preferred habitat, is low oxygen levels. This seems plausible. However, the study cited (Ruggerone 2000), actually found that coho fry were present in Black Lake, Alaska, which had very low oxygen and water temperature levels. Ruggerone also found that coho fry could tolerate much lower oxygen levels than sockeye fry. Oasis did not report on either winter oxygen levels or water temperatures in beaver ponds, which would have helped in the interpretation of the report.

Because information on salmonid habitat and behavior from more southerly climatic regimes and streams may not accurately represent what is going on in stream 2003, additional research is needed to determine the fine scale behavioral adaptations of overwintering juvenile coho and Dolly Varden in response to the extreme winter conditions present in the Chuitna River drainage. This information is essential to meeting the objective of avoiding or mitigating habitat loss. For example, do these fishes insinuate themselves into the interstices between the rocks where there are warmer hyporehic flows to avoid freezing? Do they seek groundwater seeps or areas of upwelling phreatic groundwater for the same reason?

Paragraph 4, page 31: The statement that “There was no change in the mean length of fishes captured throughout the winter (Table 4.1)” is not consistent with the information provided in Table 4.1. Table 4.1 indicates that the mean total length MTL of all tagged Dolly Varden was 110.0 ml, the MTL of recaptured tagged Dolly Varden was 103.0mm,
and the MTL of all recaptured Dolly Varden was 105.20mm. The mean length of tagged and untagged Dolly Varden measured in the recapture program was 5 to 7mm shorter than the mean length at the time of a tagging. The same is true for juvenile coho. The mean total length MTL of all tagged coho was 72.90mm, the MTL of recaptured tagged coho was 74.70 mm, and the MTL of all recaptured coho was 73.10 mm. Tagged and untagged coho captured in the recapture program were slightly larger than the MTL at tagging. Whether these differences in MTL are significant would depend on a statistical analysis of the two sets of data.

Paragraph 1 page 32. In simple terms, juvenile coho and Dolly Varden migrate into or remain in stream 2003 because the conditions there optimize their chances for survival during the winter. For the purpose of permitting a mine, it is important to know if other tributaries of the Chuitna and the mainstem Chuitna provide similar overwintering habitat. This is important because it appears that mining will destroy a substantial portion of stream 2003 and its aquatic resources, and mining may also adversely affect both the hydrology and water quality of streams 2002 and 2004 and diminish or displace the fish and other aquatic resources using these systems.

Paragraphs 1-3 page 33. The reasons given for lower CPUE in the winter are reasonable, i.e. coho and Dolly Varden are cold-blooded animals, and as water temperatures decline so do their body functions, including digestion and feeding. This makes the bait in traps less attractive and lowers catch rates. An alternate explanation which seems less likely, but has not been excluded, is that some fish leave the system in the fall and early winter to escape declining water levels and temperatures and migrate back in the spring.

IV. Conclusions: The study provided some qualitative information on the 3 objectives but only a limited amount of quantitative information because of the techniques used. Baited minnow traps attract and hold small fish which feed on salmon eggs from some unknown distance downstream. Large fish, age 0 and age 1 fish which are small enough to swim through the screen covering the traps, and species that are not attracted to salmon eggs are not captured. Because the coal mine would destroy a significant portion of overwintering fish and fish habitat in stream 2003 and its tributaries, information on the numbers of overwintering coho salmon, Chinook, rainbow trout and Dolly Varden using this system in relation to the remainder of the Chuitna drainage and their overwintering requirements is important. However, this study did not compare numbers of overwintering fish in stream 2003 with these other drainages. I also searched the scientific literature but was unable to find references to successful substitution of artificial overwintering habitat for natural overwintering habitat in streams that had been destroyed.

Summary:
The report provides limited but useful qualitative information on winter habitat preferences and longitudinal movements of Dolly Varden and juvenile coho tagged before October 27. Because fish were only color marked and no fish were tagged after October 27 there is no way to determine from this report if juvenile coho or Dolly Varden
moved into or out of stream 2003 after that date. Because changes in stream conditions (flow, floods, water temperature, ice formation, snow depth, location of pools and riffles), and numbers of overwintering fish could change substantially from year to year, more than one year study is necessary to meet permitting requirements. Because the proposed Chuitna Coal Mine will destroy stream 2003 and all of its aquatic life, additional studies on overwintering behavior, winter habitat preferences, instream flow, groundwater flow, and genetics are necessary to meet permitting and mitigation requirements.


Introduction: LGL’s stated objectives: (1) describe fish movements in and out of streams 2002-2004, (2) describe the effects of development on stream 2003 on production of Chinook and coho salmon smolts, (3) estimate the proportion of fish production within the Chuitna River drainage that is contributed by stream 2003, (4) describe overwintering use of stream 2003 by resident rainbow trout or Dolly Varden char, and (5) determine species composition, estimate relative abundance of juvenile Chinook and coho salmon, and establish a time series designed to detect and measure potential effects of mine development on fish production. A time series is a set of regular time-ordered observations of a quantitative characteristic of an individual or collective phenomenon taken at successive and in most cases periods or points in time. What would constitute the “time series” is not defined in the context of the proposed Chuitna Coal Mine and no explanation of how it would be used to detect and measure potential effects of mine development on fish production is provided.

Analysis and Comments:

Page 1 paragraph 2: The LGL report indicates that the work was done because stream 2003 will be “developed.” A description of how mining would change stream 2004 and its drainage would help to place the study into context and make it more meaningful.

The studies of fish production in streams 2002 and 2004 are important; however, because there appear to be physical and biological differences between these streams and stream 2003, it is unlikely that these streams can be used as controls in the destruction and reconstruction of stream 2003. In addition, hydraulic changes resulting from mining through the wetlands and aquifers, which provide summer base flow and essential winter flows to these streams, may also result in changes in nutrient levels and essential winter groundwater flow. Changes of these types would confound any comparison with stream 2003, and negate the use of streams 202 and 2004 as controls or reference reaches.

1.3.2 Objective 2. Page 4: LGL proposes that coho “smolt will be the life stage monitored because the production of these fish is closely linked to habitat conditions and because the relatively low interannual variability of smolt abundances (relative to adult returns and spawning escapements) increases the power to detect a difference after an impact.”
Given the choices, out-migrating coho smolt may be the best life stage to monitor, but it is not clear that coho smolt outmigration would be an effective means to detect impacts from strip mining. First, the assumption that there is “relatively low interannual variability” of abundance in coho smolt out abundances” is not supported by data from streams 2002-2004 or the scientific literature. I discussed this with several ADF&G fishery biologists and they do not feel that coho smolt production from Alaskan streams can be characterized as having a relatively low interannual variability (Hasbrouck 2009, Hayes 2009, and Massengill 2009). LGL’s assumption appears to be based on a few years of coho smolt data from the Kenai River and Cottonwood Creek. During this period, smolt production may not have fluctuated as much as adult escapement, but there was a reported 20-25% difference in smolt outmigration from the Kenai River and Cottonwood Creek from 2003 to 2004. However, from 1992-2007 estimated Kenai River coho smolt abundance ranged from 374,000-1,227,000, a three hundred percent difference. Massengill (2009). This is not relatively low interannual variability.

Smolt abundance may have been relatively stable over a 4- to 5-year timeframe in Cottonwood Creek and the Kenai River, but no data is available to support the assumption that smolt production from streams 2002-2004 is similarly stable. Flow, water temperatures, nutrient retention and other habitat factors that influence smolt production are moderated by the large lakes in the Kenai River and Cottonwood Creek systems, but the Chuitna River drainage has no lakes. The assumption that coho smolt production is relatively stable also assumes that streams 2002-2004 are limited by the amount of available spawning and/or rearing habitat rather than the numbers of adult coho which escape to spawn. This could be correct, but no data has been provided to support this assumption.

It is also possible that there may be natural variations in freshwater smolt survival rates between streams 2002, 2003 and 2004 that could mask the effects of mining on stream 2003. No data on smolt survival by stream is provided in the report.

Habitat related declines in salmonid populations usually occur incrementally and an annual population decline of 20-25% or much more is within the range of natural variability. Population changes of this magnitude might not be recognized as mining related until the factor causing the decline was irreversible. A Washington study evaluated eight native salmonid populations to determine if rapid, sensitive detection of a reduction in abundance was possible. The study concluded that population abundance monitoring may not provide feedback sufficiently sensitive or rapid enough to implement corrective action that prevents impacts from causing harm or exceeding an acceptable level (Ham and Pearsons 1999).
1.3.3 Objective 3, page 4, Paragraph 2: LGL proposes to use habitat modeling to determine theoretical production from stream 2003 and the theoretical contribution of stream 2003 to the Chuitna River system. This may be a worthwhile exercise; however, there are some problems. Habitat quality and quantity controls smolt production except in the rare instance where a system is spawning habitat limited. The PacRim studies and reports do not address this issue.

In order to determine how many years of data collection on smolt outmigration are necessary to determine the relative contribution of stream 2003 to the Chuitna River system, it is necessary to know how much variability there is in smolt production within and between streams 2002, 2003 and 2004 over time. One year’s data isn’t sufficient to make this determination. Smolt production is dependent on many factors, including but not limited to the number of adult spawners, habitat quality, winter survival, predation, and floods. In nearby Upper Cook Inlet streams (Little Sustina River and the Deshka River) where Chinook and coho returns have been monitored for many years, adult returns have varied by as much as 500% over a 20-year period. At times one stream may have high escapements while the other has low for reasons that can’t be fully explained. Clearly, many more years of data from the Chuitna River system are needed to determine the full range of smolt abundance. For example, how would permit or mitigation decisions be affected if next year’s catches found that stream 2003 produced twice as many smolt as 2002 and 2004? Apparently the current plan appears to be to collect only one year of data before the mine is permitted, and any subsequent studies conducted after that date, would be too late to be a factor in assessing the impact and permitting decisions.

1.3.4 page 5, The Oasis overwintering study did not provide any quantitative data on rainbow trout, a popular sport fishing species, although it acknowledged that rainbow trout were present and spawned in at least one tributary of stream 2003. Different sampling methods need to be used to provide information on species such as rainbows.

3.1: Fish Movement and Abundance in Tributaries, Page 9

Weirs: Page 10. The construction and operation of the weirs used to capture and enumerate adult and juvenile fish may have biased the data. Because of debris loads, constriction of flow, fluctuating water levels in streams and the need for constant maintenance, weir design has to be a compromise between blocking fish movements and functioning at most flow levels. LGL described the weirs used to collect data on summer and fall fish movements in streams 2002-2004 as constructed of 1.2 m by 2.4m panels and “faced with 0.64cm mesh, .95 cm mesh, or 1.27 cm mesh.” Adult and juvenile upstream migrants were enumerated by video cameras in small weir breaches.

The materials the weirs were constructed of and the manner in which passage was provided for juvenile upstream migrants probably biased the data. First, even the
The smallest mesh (64 cm mesh) is large enough to allow age zero coho, rainbow trout, Dolly Varden and Chinook fry to pass through it and avoid the holding box or the video camera chute (Bramblett et al. 2002 and Massengill 2009). As a result, these small fry may not have been captured proportionate to their real numbers. Bramblett et al. (2002), who used similar weirs in a study of seasonal juvenile coho, rainbow trout, and Dolly Varden movements in Southeast Alaska, reported that “Coho fry were captured at both weirs during May and June in 1996 and 1997, but most fry were able to pass through the 6.4 mm (.64 cm) mesh of the weir panels.” The larger mesh sizes LCL used to construct other sections of the weirs might allow a percentage of age 1 and 2 juveniles to pass through also.

3.1.2 Upstream movement and abundance of fish. Page 12. The LGL weirs do not appear to be designed to efficiently pass or count juvenile salmonids that were migrating upstream. Because the weirs used to capture and count fish were designed to force both adult and juvenile upstream migrants to locate and pass through a small breech in the middle of the weir, juvenile upstream migrants may have been undercounted. Newly emerged salmonid fry (25-35 mm) are relatively weak swimmers and seek water velocities of less than 10 cm/s (.3 fps). Larger fish (4-18 cm) usually occupy sites with velocities of no more than 40 cm/s (1.3 fps) (Bjorn and Reiser 1991). Juvenile salmonids are relatively weak swimmers and usually migrate at the margins of streams where water velocities are lower and cover is greatest.

LGL did not identify where in the weir the location of the 1.5x1.5x3 foot video breaches were located or record the velocity through these breaches in the report. Figure 6 (Photo 6) shows a weir breach located in the middle of stream 2002. Photo 7 shows water cascading (i.e. high velocity) out of the stream 2003 weir and what appears to be the video breech.
Figure 6 – LGL Weirs

Because the weirs both constricted the streams and created a hydraulic head, water velocities at the breaches were almost certainly increased significantly over ambient levels and over the velocities preferred by juvenile salmonids. The drop from the weir
appears to be as great as one foot and may have also impeded or blocked juvenile upstream migration. Mueller et al (2008) tested the leaping ability of juvenile coho salmon (60-135 mm). They found that 100% were able to pass an outlet drop of 0 inches, 4.7 inches 34 %, 7.7 inches 20%, and 10.2 inches 2%.

Under low flow levels very small up- and downstream migrants could have passed through the weir mesh and not been counted, biasing the results.

**Video system design, configuration and operation.** The description of how the video system functioned is confusing. Paragraph 4 indicates that the video system was supposed to be operated 24/7 through September. Paragraph 5 states that the system was set to record video at a rate of 7 frames per second. However, the paragraph then states that the system was set to record fish passage events at 5-second intervals through motion detection, and that most debris and juvenile fishes would not trigger the system. Does this mean that juvenile fish weren’t counted? Later the report states that fish counts were estimated by subsampling the first 15 minutes of each hour, except when fish counts were estimated by counting the entire hour during period of high adult fish movement.

**Page 13 paragraph 4:** I am not sure about the accuracy of the method used to subtract upstream migrants from downstream migrants, i.e. if 100 of a particular group or species were sighted going upstream and 50 were sighted going downstream, the upstream count was estimated to be from 50 to 100. If 100 went upstream and 50 came downstream the net should be 50 upstream. I assume that these are adults since it wasn’t specified. The method is confusing since the report doesn’t indicate how much time elapsed between upstream and downstream observations

In spawning areas, salmon often tend to cycle upstream and downstream. This can be a real problem if a weir is located within a spawning area. When I set up new weirs and counting towers in the Yukon River drainage, we counted salmon upstream and downstream 27/7 all season. We subtracted upstream migrants from downstream migrants to get the net. One complication was that fish spawning in the area would cycle through the weir continuously, and spawned-out fish would often swim downstream past the weir. If LGL encountered this problem, it isn’t mentioned in the report.

**4.0 Results page 23.**

4.1.1 Tributaries: Because the weirs were not in operation or completely sealing the streams for varying periods due to high water, combined with the fact that age zero and some age 1 fish could swim through the mesh on the weirs, it is not possible to conclude with a high degree of confidence that “Fish sampling provided a complete or near complete census of downstream migrating fish.”

Video detection of fish moving downstream: Page 26. LGL mentioned species identification as an issue. It is possible that there was some error in distinguishing between juvenile coho and Chinook salmon in the holding boxes, and if so there would have been a similar error in estimating composition of the fish passing through the video
chutes. Identifying juvenile Chinook and coho salmon in the field can be challenging. To see how similar juvenile coho and Chinook salmon appear, look at the pictures of juvenile coho and Chinook salmon located at www.fpc.org/bon-da/juvsalmon.html.

Page 27 paragraph 2. LGL did not explain how they distinguished small juvenile rainbow trout from other salmonids on the video tapes. LGL apportioned video coho counts based on composition of the juvenile salmonids in the holding box because it was more reliable than trying to identify juvenile salmon from video tapes under less than ideal conditions. To see how similar juvenile coho salmon and rainbow trout look refer to the pictures located at www.fpc.org/bon-da/juvsalmon.html. Age zero and likely some age 1 rainbow trout were small enough to pass through the weir mesh and an unknown but possibly significant number may not have been counted at the weir or video chute (Bramblett et al 2000). LGL cited mesh size as a reason juvenile rainbow trout were captured in the smaller mesh stream 200401 fyke net but not the larger mesh nets or weirs used in the study.

There are other indications that there may have been problems with using the video chutes as the primary method to enumerate upstream adult and juvenile migration. First, the upstream and downstream counts for adult sockeye salmon in stream 2004. Table 8 indicates that 44 adult sockeye migrated upstream and 48 migrated downstream. Because no more adult sockeye could migrate downstream than upstream, either the upstream counts or the downstream counts are incorrect. Second, the video cameras apparently did not record over the same period of time. Tables 6-8 indicate that the stream 2002 video camera operated from June 8 through September 29, but the cameras on the other two streams only recorded upstream and downstream migrants from June 29 through September 29 and September 30 respectively. I could not find any explanation of how this apparent discrepancy was addressed in the report.

4.2.2 Run timing and biological characteristics of juvenile coho salmon: page 28.

Stream 2002: page 28. There are some anomalies in the stream 2002 catches, which raises questions about the data. First, the disclosure that juvenile coho (less than 90mm) were captured as soon as the weir was installed on June 4 and peaked two days later on June 6 indicates that downstream movement began some time earlier and that a significant portion of the run may not have been counted. LGL also reported that they used partial weirs and fyke traps intermittently between May and June 4 to enumerate migrants. These methods would not capture all fish moving upstream and downstream and calls into question the accuracy of pre-weir counts and species allocations for stream 2002-2004.

Second, in stream 2002, 2,512 fish were caught in the weir and another 6,367 were observed to have moved through the video chute. In contrast, in stream 2003, 7,394 fish were captured at the weir and 366 fish were estimated to have passed through the video chute. In stream 2004, 4,085 fish were captured at the weir and 856 fish were estimated
to have passed through the video chute. No explanation is given as to why most of the fish in stream 2002 chose the video chute over the weir. Because LGL rightly considered the weir counts to be more reliable than the video estimates, and used the species composition of the weir counts to apportion the fish in the video counts between species, this discrepancy calls into question the accuracy of the stream 2002 species counts.

Page 32 paragraph 4: Chum salmon. Like other age zero fish species, including rainbow trout, chum salmon fry are relatively small and even if present in large numbers would be less likely to be captured in the weirs and large mesh fyke nets used in the study. Chum fry also feed on small insect larvae in freshwater and might not be attracted to salmon egg bait in minnow traps (Groot and Margolis 1991).

Page 32 paragraph 6. Adult coho salmon: It is surprising that only 13 adult coho were captured in the weirs through September 30 considering the relatively large number of coho spawning in the three study streams. When coho are spawned out they tend to drift downstream and pile up on any obstruction such as a weir. Were the weirs pulled before the end of spawning?

Page 35 paragraph 1: The average size of the rainbow trout sampled in stream 200401 was 35 mm. This means that they would be able to pass through the mesh of the weir panels, which were greater than 0.64 cm and the larger mesh fyke nets and would not have been sampled effectively in the mainstem of streams 2002-2004.

4.3.2 CPUE and run timing of fish groups moving upstream

Page 37 paragraph 4. The authors report that there were distinct pulses of adult coho salmon entering all three streams on September 3 and 7 as shown in appendices E, F and G. This is consistent with data from other Cook Inlet streams which indicates that upstream coho movements are triggered by high water events (Hayes 2009 and Kerkvliet 2009). Pulses also entered 2002 and 2003, and probably 2004, but the authors indicate that “the water in stream 2004 was too high to count fish by any method.” LGL also reported that the inability to see into the high and turbid water “may have partially accounted for the smaller number of fish seen returning to stream 2004.” This makes sense, and yet Appendix G for stream 2004 contains video and video-expanded counts for September 3, 7 and the remainder of September. This discrepancy raises the question of what was the actual size of the coho run into stream 2004, as well as whether the same high water event also affected the accuracy of counts at streams 2002 and 2003. To evaluate the data it would be useful to know what the turbidity levels were and how far from the video camera fish could be seen at various turbidity levels.

4.3.5 Visual counts during flood events, page 39: This section indicates that due to flood events in September when the video camera wouldn’t work, and when sections of the weir were removed to allow flood waters to pass, salmon passing the weir sites were counted by observers on the banks. These counts may not have been accurate. If the
water is shallow and clear, counting salmon in flood waters in a small stream during daylight hours may be feasible. During floods, however, waters are usually high and turbid. If it is raining and cloudy and light levels are low, it is difficult to see fish moving upstream in turbid waters. LGL reported that the inability to see into the high and turbid water “may have partially accounted for the smaller number of fish seen returning to stream 2004” but did not mention this as a problem for the other streams during similar high water events.

I did not find any depiction or description of hourly fish movements in the report. Salmon run upstream 24 hours per day, and upstream movements of adult Chinook and coho salmon in Cook Inlet streams are usually triggered by high water events (Hayes 2009 and Kerkvliet 2009). The report doesn’t explain how fish were counted during the hours of darkness when the water was deep and turbid. During the September 9 high water event, for example, the sun rose at 0713 and set at 2039 which means that there was only about 11 hours of daylight. There was no mention of artificial lighting over the streams in the report and no evidence of it in the photos of the weirs. Without supplemental lighting over the creek, it would be extremely difficult if not impossible to accurately count fish at night in a flood.

4.4 Abundance of coho and Chinook salmon smolt in the Chuitna River drainage, page 39. More research is needed on the tag and recapture methods used to estimate Chuitna River coho smolt abundance. The accuracy of Peterson type population estimates depends on at least three basic assumptions: the population has to be closed (i.e. no fish die, immigrate, emigrate, or lose their tags), the fish have to be smolting and the marked individuals must distribute themselves within the marked population so they have an equal chance of being captured (Gatz, J, and J. Loar 1988). Because coho smolt are migrating out of the Chuitna River sampling area and leaving the population and other coho smolt are moving into the sampling area from tributaries without weirs, it is not a closed system. It is also not known if smolt out migrating from the different natal streams mix uniformly within the Chuitna River population. Another problem which other Cook Inlet researchers have encountered in estimating smolt numbers from tag and recovery data is uncertainty as to whether all downstream migrants are smolting or just moving (Kerkvliet 2009).

4.5.2 Temperatures, page 40 paragraph 6. The surface water temperatures reported by LGL for Chuitna River tributaries in early May, 0-1 degrees C, are within the range found to be lethal to coho, Chinook, sockeye, and chum salmon and rainbow trout (Bjorn and Reiser 1991). Mid-winter temperatures would likely be lower. To survive the winter, fish would have to move to areas warmed by groundwater (Huusko et al 2007 and Bradford et al 2001). Bradford et al (2001) investigated the overwintering behavior of juvenile stream type juvenile Chinook salmon in Croucher Creek, a small upper Yukon River tributary. They found that most of the fish that successfully overwintered spent the winter in a 700 m reach of the creek that was downstream from groundwater sources and did not experience severe icing conditions. The study concluded that small streams may be important habitats for juvenile salmon in cold climates, especially if there is a year-round source of groundwater flow that creates conditions suitable for overwintering.
Phreatic groundwater flow is clearly the critical factor in enabling juvenile salmon to escape freezing temperatures in cold climates. Locating areas of groundwater and understanding how it is propagated and enters streams 2002-2004 is critical in determining the effects of mining on these three streams and the chances for successful restoration of stream 2003.

4.5.4. Precipitation, page 42, paragraph 2. LGL found that heavy rainfall resulted in high water events and “during these high water events that our sampling equipment was most likely to have reduced effectiveness, and in some cases halted all together.” Nets and weirs plug up with debris and are often carried away by high water. This is a common problem with operating weirs, traps and nets in rivers, and it is important because upstream coho and Chinook migration is often triggered by high water and cooler water temperatures associated with increased precipitation (Frazer et al 1983, Hayes 2009, Kerkvliet 2009 and Holby et al 1984). If most coho moved upstream during the high water periods when LGL’s “sampling equipment was most likely to have reduced effectiveness, and in some cases halted all together,” the adult coho counts were likely too low. However, I did not find anywhere in the report a clear explanation of how high water and equipment malfunctions may have quantitatively affected adult and juvenile or how LGL compensated for lost or impaired fishing or data collection time.

The scientific literature indicates that age zero salmonid fry may be flushed downstream during high water events (Bjorn and Reiser 1991 and Branbletts et al 2002). Some of these fry could rear in the portion of the Chuitna below the weirs or in the nearshore waters of Cook inlet and return as adults but currently would not be counted as smolts produced by streams 2002-2004. These fry would be too small to be easily seen and counted by shoreside observers in turbid waters.

5.0 Discussion:
5.1. Overview of fish species composition in tributary streams
5.1.2 Basic run timing of key fish species. Page 44 paragraph 1-2. A study of the timing of smolt migration from the Chuitna River to Cook Inlet would help put the Chuitna fish studies in context, including the population estimates.

Page 43 paragraph 1: The revelation that the rainbow fry in stream 2004 and 2004-1 were “caught with a smaller net fyke net than was used in other systems” underscores the problems with catching rainbow fry and other small salmonids in minnow traps identified in the Oasis 2007 winter study. It is possible that rainbow and age zero Chinook fry were present in larger numbers in all three systems but were not captured by the relatively large mesh in the nets, traps and weirs used by LGL.

Page 43 paragraph 3: LGL’s explanation of why the estimated 2008 Chuitna coho escapement was much larger and the estimated 2008 Chinook escapement much smaller than ERT estimates from the early 1980, i.e. natural population fluctuations, seems to be the best fit. Other possibilities include errors in the 1980’s data or increased harvest of
returning adults by the Cook Inlet commercial fishery. As previously discussed, escapement data from the aerial and foot surveys used to enumerate these species have a wide margin of error. Weir and sonar counts are the most reliable. Because only a couple of years of intensive scientific sampling have occurred, it is not possible to accurately estimate what the full range of adult salmon escapements to the Chuitna may be.

5.1.2: Basic run timing of key fish species. Page 44. Paragraph 3. The finding that “The bimodal run of coho into the Chuitna watershed was consistent with observations from 1982 and 1983 (ERT 1984) when coho were detected in late July and again in August” is important. It gives additional support to the likelihood that there are genetically distinct demes of coho salmon in the Chuitna River and its tributaries. There is an increasing body of scientific evidence that coho, Chinook and sockeye salmon that aggregate for breeding at spatially defined habitats have evolved into discrete populations with special genetic or physical adaptations for those habitats or demes (Stewart et al 2004, Fisheries and Oceans Canada 2009, and Brykov et al 2004). The idea that there are reproductively isolated demes in the Chuitna system is supported by recent genetic analysis which found that juvenile coho salmon stocks collected from 8 spawning locations within the Kenai River drainage are genetically subdivided (Crane et al 2009). The genetic makeup of Chinook and coho salmon stocks in the different tributaries of the Chuitna drainage is an important factor in assessing impacts and determining the feasibility of restoring stream 2003 after 20 years of mining. If a coho deme which is adapted to the unique conditions in streams 2002, 2003, or 2004 is destroyed, it is possible it can’t be replaced. The genetic composition of stocks in the Chuitna River and the three streams likely to be impacted by mining should be analyzed.

Page 44. Reported differences in Coho and Chinook run timing between the 1980’s and 2008 could also be the result of the observed 3- to 5-degree C increase in water temperatures in some Cook Inlet drainages (Kyle and Brabets 2001). If water temperatures in the Chuitna River drainage are increasing, this will stress fish populations adapted to colder temperature regimes and have important implications for restoration. Temperature trends in the Chuitna river drainage need to be determined as part of the environmental studies and factored into the environmental impact assessment process.

Page 45 Rainbow trout: The discovery of a large migration of age zero rainbow trout in stream 2004-01 using a smaller mesh fyke net may be indicative of a bigger problem with the 2008 study. As stated in the report, sampling using weirs and fyke nets with mesh greater than 4 mm was not optimum for capturing small, newly-hatched fish of any species, including Chinook, coho, and Dolly Varden. For example, Bramblets et al (2002) found that most salmonid fry (less than 38mm in length) “were able to pass through the 6.4 mm mesh of the weir panels.” Additional systematic quantitative premitting sampling needs to be done in streams 2002-2004 with smaller mesh gear to determine if significant populations of these age classes of fish were overlooked in previous studies.

5.2.1: Life history of juvenile coho salmon:

Page 46: Paragraph 2. If the LGL weirs and fyke nets physically blocked, impeded or created water velocity barriers to upstream migration of age 0 and age 1 salmonids, it could explain why “We (LGL) did not see a reciprocal movement upstream (summer and fall) indicating that these downstream movements represented an overall redistribution in the watershed…” Bramblett et al (2002) studied in-stream coho movements in Southeastern Alaska, but with different results. Bramblett found that juvenile coho left mainstem Stanley Creek in late summer and fall and migrated upstream into tributaries, and that a large immigration peak occurred in October. In August through December 1996, 50% of juvenile coho captured in the Tye Creek weir were going upstream. In 1997, more coho were captured going downstream than upstream, indicating that some as yet unknown factors govern instream juvenile coho movements. In 1997, most juvenile steelhead captured at weirs on tributaries moved upstream from mainstem Stanley Creek into tributaries during the fall as flows increased and temperatures decreased. Bramblett et al observed that fall juvenile salmonid movements coincided with declining water temperatures and rain-induced fall freshets common during October in both southeastern and southcentral Alaska. Similar juvenile coho movements have been documented between tributaries in the Kenai River drainage (Hsbruck 2009). Additional study of juvenile fish movements in the Chuitna is warranted, using sampling gear more suited to small juvenile fishes and extending later in the fall.

Page 46 Paragraph 2-5. Because the question of the contribution of age zero and age 1 downstream migrants to coho salmon production in the Chuitna is important to the permitting and mitigation process, additional pre-permitting study is warranted. Miller and Sadro (2003) found that “Nearly half of each (coho) brood year moved to the estuary as subyearlings, a portion of age zero juveniles that moved downstream during spring lived in the ecotone through summer for 8 months, then most moved back upstream to winter.” After these fish spent 1 to 2 years in this ecotone, their scales would show 1-2 years residence in freshwater. Because there was no sampling in the Chuit River below the rotary screw traps or after September 30, there is no way to determine what contribution these age 1 and zero out-migrants may make to total Chuitna River coho production.

Smolt Status page 47 paragraph 1: The reports states that “Prior studies in upper Cook Inlet show that adult coho salmon returns are primarily fish that migrated at age 2 (e.g., two winters spent in freshwater) with the addition of some fish that migrated at age 1.” This statement doesn’t resolve the question of the potential contribution of the age 0 and 1 coho fry that migrated out of streams 2002-2004, because the 2009 study did not look at what those fish did after they left these streams. These fish could spend 1-2 winters in the lower Chuitna, migrate into other Cook Inlet drainages to rear, or migrate upstream after September 30 to winter in streams 2003-2004, smolt and then return as 1-2 check adults.
Page 48 paragraph 1. I agree with LGL’s conclusion that existing information on juvenile salmon life history needs to be “augmented with studies within the mainstem river and with studies of habitat survival by age-1 coho salmon to explain the reason for emigration from the tributaries to the river by pre-smolt coho salmon.” The current studies leave unanswered a lot of important questions relevant to the environmental and permitting process. (See Appendix 2.)

Page 52 paragraph 1. I agree that LGL’s “estimate of smolt abundance in the Chuitna also appears low when considering likely numbers of adult fish that return to this watershed.” A 32% smolt to returning adult coho survival rate seems very high. By contrast, coho smolt to adult survival rates from other Alaska coho populations have ranged from 1.1% to 11% (McHenry 1977, Dudiak et al 1990, and ADF&G 2007). This high survival ratio could indicate that the number of smolt produced by the streams was much higher than the 2008 estimate indicates. However, it could also mean that LGL’s estimates of adult escapement are too low because of problems with the use of aerial and foot surveys to count salmon and with the operation of LGL’s weirs during high water events that were discussed in previous sections. Additional research is needed to determine smolt abundance in streams 2003-2004 and the Chuitna River as well as freshwater and marine survival rates. More accurate counts of adult salmon are also needed.

It also seems likely that the lower 8 miles of the Chuitna, which was not sampled, provides coho rearing habitat and that it could support up to 10 percent of the rearing coho in the system. It is possible that a percentage of the age 1 and age 2 coho smolt produced in this section of the drainage consist of coho that migrated downstream from streams 2002-2004 as age zero or age 1 fry. Several studies indicate that coho nomad (i.e., age 0 downstream migrants) life history strategy includes spring/summer rearing in estuarine habitats as age zero fry and an upstream migration in fall for overwintering before smolting (Koski 2009). Estuarine rearing age zero coho have been reported from a number of coastal Alaskan streams’s, including streams in Cook Inlet (Koski 2009). Because they would be from the same year classes as the smolt captured in the weirs and screw traps, the percentages of smolt produced by streams 2002-2004 would not change.

5.4 Abundance of Chinook Salmon Smolts in Tributary Streams Versus the Chuitna River Watershed. Any or all of the three possible reasons given in the report (i.e. Chinook fry tend to rear in larger streams, misidentification of Chinook fry and smolt (previously discussed), and low adult escapement into the Chuitna) could explain the low number of Chinook smolt and fry captured in 2008. A number of years of good data (10–20) are necessary to make responsible science-based decisions on the dynamics of salmon stocks. In 2007, adult Chinook escapement into the Deshka River, the closest North Cook Inlet stream where Chinook escapement is monitored, was far below the five-year average, The 2008 Chinook escapement was only 7,533, down from a high of 57,939 fish in 2004; this represents a change of over 700%(ADF&G 2009). Because salmon populations experience large natural fluctuations for reasons we do not fully understand, it is
problematic to make decisions on the impacts of a mine based on just one or a few years of data.

6.0 Conclusions and Summary of Key Results

6.1 Objective 1 page 55: Describe the movements and abundance of fish moving into and out of streams 2002, 2003 and 2004. For reasons presented earlier in this review, it is not safe to conclude that “The abundance and timing of numerous fish species moving to and from streams 2002, 2003, and 2004 were described thoroughly from late spring through mid fall in 2008.” For example, it was reported that juvenile coho (less than 90mm) were captured as soon as the weir was installed on June 4 and peaked two days later on June 6. This indicates that downstream movement began some time earlier and was not thoroughly documented. A significant number of adult salmon and juvenile fish could also have moved through the weirs during high water events when the weirs and video monitoring equipment was down. The mesh on the weirs and fyke nets was too large to effectively sample age zero and possibly some small age 1 salmonids because they could pass through it.

Page 57 paragraphs 1 and 2: The low numbers of adult and juvenile Chinook salmon in streams 2002-2004 in 2008 was likely the result of natural population fluctuations and cycles rather than any fundamental change in species composition. For example, the 2008 Chinook escapement into the Deshka River, another upper Cook Inlet stream, was 1/5th, and the 2007 escapement was 1/2, of the 5-year average from 2002-2006.

The 2007 and 2008 Deshka River coho escapements were also ¼ and 1/3, respectively, of the 5-year average from 2002-2006, indicating that both the Chinook and coho runs into the Chuitna during the same time period could have been well below average. Experience from the Deshka River indicates that at least 5 years and up to 20 years of study may be necessary to determine the full range of escapement/production from the Chuitna system.

6.2 Objective 2: Describe the effects of development on stream 2003 on production of Chinook and coho salmon smolts. The report does not describe the effects of development of the PacRim Coal Mine on stream 2003 or the process by which the data collected on smolt outmigration from streams 2002-2004 would be used to describe the effects of strip mining on stream 2003. We can assume that the effect of the mine will be to completely remove the upper 40% of the 2003 watershed as well as the fish habitat and fish stocks that currently exist. Because this area contains most of the spawning and rearing habitat, fisheries production in stream 2003 would decline significantly. Significant portions of the 2002 and 2004 watersheds would also be removed, with attendant effects on groundwater flow, water quality and very likely on fish production. This would bias any attempts to use these streams to monitor effects on stream 2003.

There are many studies which show that the large-scale watershed clearing, excavation, and development associated with strip mining adversely impact salmonid populations

Unfortunately, the scientific methodology available to estimate cumulative effects from coal mining in the Chuitna River drainage remains limited (Harvey and Railsback 2007). Although other fisheries scientists have proposed methodologies to estimate multifactor cumulative watershed effects on fish populations no plan is laid out in the LGL report (Harvey and Railsback 2007).

6.3. Objective 3. Estimate the proportion of fish produced within the Chuitna River drainage that is contributed by stream 2003. The title of this section is misleading since the only estimate provided for all of the species of fish and age groups of fish produced by stream 2003 (i.e. Chinook salmon, rainbow trout, Dolly Varden and age 0 and 1 coho salmon that did not migrate downstream) was for out-migrating fish judged to be age 1, 2 and 3 coho smolt.

LGL has provided an estimate of the proportion of coho salmon out-migrating from stream 2003 in 2008, but for a number of reasons it is not clear that this is the real number of fish that actually left these streams. There were several problems with the study that raise questions about whether the definitive estimate for coho smolt produced in stream 2003 is really 20.8% of the total. These problems include: the inability to count or accurately estimate the number of fish during high water events; the fact that an unknown number of fish migrated downstream before the weir was installed; age zero and likely some age 1 coho fry were small enough to pass through the mesh of the weir and were therefore not counted; because most of the downstream migrants on stream 2002 passed through the video chute rather than the trap, an unknown percentage of the fish may have been misidentified as to species or misclassified as smolt because of the difficulty of identifying small, similar-looking fish from fleeting video images; and it isn’t clear that all of the basic requirements for a Peterson mark and recapture population estimate (i.e. a closed population) were met. Although LGL based the estimate of pooled 80-161 mm coho smolt abundance in stream 2003 on a Darroch-Peterson best estimate of 37,424 smolt in the Chuitna drainage, the 95% confidence limits for this estimate were actually a range of 33,276 to 41,572 fish (Table 14).

Page 79 Figure 3. Figures 3 and 4 indicate that during the study period, peak flows reached as high as 400-1000 cfs, and in some instances these flows lasted for days. Problems such as these resulted in the sampling gear not fishing, partially fishing, or overflowing (weirs). Figure 5 illustrates this problem and how it would have affected counts. This figure indicates that the sampling gear was not “operating normally and fish tight” roughly 40% of the time in stream 2002, 50% of the time in stream 2004, and 60% in stream 200401. This means either no data was collected during these periods or the data collected was compromised. Because high flows would have been accompanied by
increased turbidity, it would be very difficult to observe adult salmon and almost impossible to observe small fish and salmon fry. High water velocities (greater than 2-3 fps) caused by high flows and constriction of the stream channel by the weir would have prevented or impeded the upstream movements of juvenile salmonids (Bjorn and Reiser 1991). The report did not adequately address this problem.

Page 127-131 Photos 1-7. These photos (Figure 6) illustrate my concern that the weirs appear to have blocked or impeded upstream fish passage particularly for small fish, and may not have effectively sampled upstream migrants. The weirs blocked the entire stream channel and created a hydraulic head and increased water velocity in the sections of the weir that were left open. At higher water levels, the problem would have been greater. Pictures 7, 14 (stream 2002), 17 (stream 2003) and 19 (stream 2004) in particular show water cascading from the weir and creating what appears to be both a velocity and a height barrier for juvenile fish. I did not see any indication in the report that LGL measured water velocities in the breaks in the weirs or the video chutes, which were supposed to allow upstream passage, to determine if the water velocities in these breaks were impeding upstream fry movements. Velocity barriers to juvenile fish passage would have reduced the numbers of juvenile salmonids that would have otherwise moved upstream without the weirs, thereby biasing the results in favor of downstream migrants.

Summary:
LGL installed and operated a weir system to monitor upstream and downstream fish movements on streams 2002-2004. Because of difficult operating conditions and problems with the weir design, which allowed some fish to pass without being counted or identified as to species and which may have blocked or impeded upstream fish migration by small fish, the counts of upstream and downstream migrants were probably low.

Juvenile salmonids that were believed to be smolting were tagged at the weirs and recaptured in rotary screw traps (RSC) at approximately mile 8 of the Chuitna River. The ratio of tagged fish to fish captured in the rotary screw traps was used to make a modified Peterson estimate of the total number of smolt produced in the Chuit drainage and in stream 2003. Because the study area may not have been a closed population, juvenile coho salmon that may be rearing in the lower 8 miles of the Chuitna River were not included in the study; for this and other reasons, the estimate of both the total number of smolt in the Chuitna and of those produced by stream 2003 may not be correct.

This study provided some new information on the movements of fish within these streams between May 8 and September 30, 2008. The report did not, however, meet its objective of “describ[ing] the effects of development on stream 2003 on production of Chinook and Coho salmon smolts.” It confirmed that wintering use of stream 2003 by resident rainbow trout and Dolly Varden char occurred, but didn’t provide any information on the overwintering population that remained above the weirs and didn’t migrate downstream. No information was provided on potential fish movements during breakup and after September 30. Fish were clearly moving downstream prior to
installation of the weirs in the spring, and LGL postulated that fish may move upstream in October (Section 6.4 Objective 4).

It is not clear how the report established, as it claimed to, “a time series designed to detect and measure potential effects of mine development on fish production.” There was no description of how the mine would affect fish production and how the data provided in this report would be used to detect changes. This would be a very important product, and since it is critical to the environmental and regulatory processes, it is important that these impacts and the proposed process for detecting them be described for agency and public review as soon as possible.

The plan to use streams 2002 and 2004 as controls to detect changes in fish production in streams 2003 is problematic because streamflow, water quality and fish production could be affected by the mining proposed in all these drainages. Shallow groundwater flow, which appears to provide critical summer and winter refugia for fish in streams 2002 and 2004 might also be affected by mining and pumping in the stream 2003 drainage.

The LGL report provides some useful information subject to the previously discussed limitations, but one year’s weir and tagging data is insufficient to draw conclusions on the life history, habitat use and requirements, overwintering behavior, abundance, survival rates, species composition and movements of fish within the Chuitna River drainage. Anadromous salmon populations fluctuate substantially from year to year due to changes in the number of spawning adult as well as fresh water and marine survival rates. Freshwater survival rates are controlled by climate variability, which in turn controls critical factors such as winter streamflow and water temperatures (Lawson et al 2004). It could take 10 to 20 years of intensive study to determine how climatic changes affect fish production in the Chuitna River drainage, and an equal amount of study to determine how fish survival is affected by changes in streamflow and water temperature regimes. There are also questions about some of the 2008 data and how the data was collected that can only be answered with improved study methods and a number of years of additional study.
Introduction: Objectives of PacRim’s Plan:

1. Provide options to minimize or prevent adverse impacts to freshwater fish resources;
2. Describe mitigation options and plans during operations to offset habitat disturbances; and
3. Present design-build plans in sufficient detail to demonstrate the ability to reconstruct portions of stream channel habitat to be removed during operations and provide a framework for post-reclamation monitoring to assess overall success of habitat construction.

The Fish and Wildlife Protection Plan (hereinafter referred to as the Plan) proposes to employ several types of protection measures to minimize or prevent disturbances to fish habitat to the full extent practical. These measures include operational procedures, construction designs, and restoration where disturbance is unavoidable. During and after operations, on-site mitigation in the form of stream reconstruction, modification, and enhancement will occur. Offsite mitigation is an option to consider offsetting habitat loss during operations but before reclamation.

The overall approach of the plan is to minimize impacts to fish habitat; mitigate for those impacts with offsite enhancement and recovery projects; reconstruct impacted channels to a natural state that provides fish habitat in a pre-mining capacity; and measure and assess the effectiveness of these activities.

Analysis and Comments:

Page 1: The Plan states that “Stream designs are prepared as design-build plans to allow for the subtleties of streambed topography that are difficult to describe in detail in a set of plans. An experienced, on-site designer during construction will be integral to this approach, and can easily incorporate these features.” Although it’s not entirely clear, this seems to indicate that regulators will be asked to approve a conceptual plan for reconstruction of stream 2003 and the final design would be developed during construction. Because there is no evidence that a strip-mined salmon spawning and rearing stream and its associated aquifers and watershed has ever been successfully restored and there are questions about the use of the Rosgen methodology to restore salmon streams, a detailed stream and watershed restoration plan should be required as part of the environmental review process. The restoration plan must include examples of where the proposed methodology and techniques have been successfully used in an analogous situation.

Page 3: The Plan states that “During mining operations, physical conditions will be maintained by keeping base flow and stream flow regimes as close as possible to pre-mine conditions.” I could not find any indication in the Plan or in other Chuitna Coal
studies that the appropriate reaches of streams 2002-2004 have been adequately gauged or that instream flow needs in stream 2003 are known. To maintain pre-mining instream flow needs of fish and aquatic life in stream 2003, it is necessary to measure flow continuously over a long period of time (5 to 20 years) to determine what these instream flow needs are. The Department of Natural Resources requires the Alaska Department of Fish and Game to have a minimum of five years of stream gauge data to grant instream flow reservations to protect fish spawning and rearing and migration (Klein 2009 and Westphal 2009). It would seem reasonable to require at least as much data for a project that proposes to eliminate and subsequently restore fish habitat and stocks.

The Plan states that “Stream discharges, water temperature, and water quality must be suitable during at least a portion of the migration season.” This statement is troubling because some life stages (i.e. eggs, fry, smolt and adult fish) are present in the streams affected by the proposed Chuitna Coal Mine at all times. For this reason stream discharges, water temperature, and water quality must be suitable at all times. Even with modern erosion and water quality protection measures in place, coal mining will likely increase surface water temperatures, silt, and turbidity and alter streamflows (Martin and Platts 1981, May et al 1997, and Ruediger and Ruediger 1999). Altering instream flow regimes in these streams is likely to result in changes in water temperature and the wetted perimeter (ie amount of available habitat) which in turn will negatively impact fish and other aquatic life.

Page 5: The proposal to capture and remove fish from the areas to be mined and release them in the unmined sections of stream 2003 below active mining is commendable but probably futile. If stream 2003 is rearing habitat limited and at carrying capacity, these fish probably wouldn’t survive because there probably isn’t sufficient rearing capacity in the rest of the system to support them. Eliminating or degrading a substantial part of the rearing area in stream 2003 and possibly streams 2004 and 2002 will reduce both the spawning and rearing capacity of these streams. None of the Chuitna Coal studies have addressed whether stream 2003 and the Chuitna River system is spawning or rearing habitat limited. This needs to be determined before mitigation plans are finalized or approved.

Page 6 Water Management: The Plan claims that all discharges will meet state water quality standards and NPDES limitations and that freshwater habitats downstream of the mining activity in stream 2003 and in streams 2002 and 2004 will be maintained by providing minimum baseline flows in each stream. These claims are easy to make in a permit application but very hard to achieve in practice. For example, similar statements were made in the Red Dog Mine and Kensington Mine EISs and permit applications, but both of these mines have violated state water quality standards. Teck Cominco has been cited by the EPA for hundreds of water quality violations since the Red Dog Mine began operating in 1989 (ADN 2006). Because maintaining existing water quality and instream flows is essential to maintaining and restoring fish populations, a credible plan to maintain existing water quality and instream flows and the data to support it must be part of the environmental review process.
The Plan claims that freshwater habitats downstream of mining activity in streams 2003, 2004 and 2002 will be maintained by providing “minimum base flows” through a “variety of methods and infrastructure” including “sediment ponds, diversion structures, infiltration basins, pumping locations, estimates of water volumes and water-balance information, and runoff control structures.” These claims raise a number of concerns given that there has been no comprehensive instream flow study of these streams. First, simply maintaining “minimum base flows” for the decades the mine will be in operation will not maintain downstream fish habitat for salmonids. Baseflow or base runoff is comprised largely of groundwater effluent (USGS 2009). The instream flow needs of salmonids vary by species, stream size, and life stage (Vadas 1999). Spawning salmon require higher flows in small streams than in large rivers. High flows provide the stimulus to coho and Chinook salmon to move upstream to spawning grounds in the Cook Inlet basin (Hayes 2009 and Kerkvliet 2009). Periodic flood flows are also necessary to remove undesirable accumulations of sediment from stream gravels so that it can continue to provide suitable habitat for salmonids and aquatic life (Milhous 1998). Because no long-term instream flow study has been conducted in streams 2002-2004, there is no way to know what flows have to be provided at different times during the year, including high flows during the spawning season, to maintain fish populations, and there is no way to determine if PacRim’s proposed system can provide them.

Second, the complex system proposed to maintain flows presents a substantial risk. One power or equipment failure in the coldest part of the winter could cut off flow to stream 2003, resulting in the loss of fish and other aquatic life. The survival of salmon and other aquatic life in cold climates depends on the continual input of warm groundwater base flow during the coldest winter months. Upstream mining and groundwater pumping will diminish or eliminate this flow. There is also a strong possibility that infiltration basins, settling ponds and bypasses that have been proposed to maintain minimum base flows will freeze up, or deliver during the winter water that is below salmonids’ thermal tolerance.

Although infiltration basins have been used in many areas to treat stormwater and recharge groundwater, I was unable to find any studies in the scientific literature documenting the successful use of infiltration basins to maintain groundwater flow to a salmonid stream or to maintain a salmonid stream in a cold climate. The use of infiltration basins to maintain flow to stream 2003 and possibly 2002 and 2004 would be experimental and would be complicated by the fact that the loss of groundwater from these streams would be the result of a cone of depression created by deep mining and pumping to dewater the mine. An independent hydrologist should review the data to make sure that the water from the infiltration basins wouldn’t be drawn to the pumps instead of the streams.

Lost Habitat Mitigation:

*Off channel spawning and rearing habitat:* The Plan discusses some of the disadvantages of attempting to create artificial spawning and rearing habitat to compensate for the loss of 17.4 km of high-value spawning and rearing habitat for 5
salmon species, Dolly Varden and Rainbow trout, but there are other disadvantages as well. First, there is a substantial probability that a functional spawning channel couldn’t be constructed. It appears that only one successful salmon spawning channel has been constructed in Alaska and an attempt to extend it was not successful (Lachmar et al. 2007). Second, not all species of salmonids found in stream 2003 use artificial spawning channels. Most importantly, unless the equivalent of 17.4 km of new rearing habitat can be created for salmon fry produced in a spawning channel, which does not seem feasible, the fry produced in a spawning channel probably would not survive and would not offset the loss of production from stream 2003.

Pages 8-13. Off-Site Mitigation: A number of offsite mitigation measures are proposed, but they do not appear to offset fish losses from mining activities. Any potential benefits of the proposed offsite measures must also be evaluated against the certain loss of 17.4 km of high-value spawning and rearing habitat in stream 2003, and additional potential losses in streams 2002-2004. No such analysis is provided for any of the proposed projects.

Some of the proposed measures -- such as bank stabilization for the Theodore River, constructing a bridge across Threemile Creek, and repair of the Theodore River Bridge, which is owned by an oil company -- offer little or no benefit to fish. Others -- such as restoring Threemile Lake sockeye stocks by eliminating introduced northern pike -- probably have little chance of success because of the limited success of rotenone in removing pike from a system with wetlands, an outlet stream, and ground water inflow. The proposal to remove the Big Lake dam is puzzling because the dam has already been removed (Ivey 2009).

Replacement of culverts that are blocking upstream fish passage can benefit fish populations if studies show that suitable fish habitat exists upstream of the culvert. There is no indication that any studies have been done to show that replacing these culverts would substantially increase fish habitat. There are already a number of ongoing programs to identify and fund culvert replacement in the Cook Inlet region. The Department of Fish and Game also has the authority under AS16.05.840 to require the owner of a dam or obstruction to fish passage to remove it.

Page 14: The Plan states that “Technologies and materials now exist that will allow for reconstruction of the 2003 stream channels in a manner that will support pre-mine riverine ecological processes.” This statement needs to be supported with examples from the scientific literature of successful salmon spawning and rearing stream/drainage restoration in strip-mined areas. No examples have been provided by PacRim and I have searched the scientific literature and talked to a number of stream restoration experts but have been unable to find any examples.

Similarly, the Plan’s statement that Stream 2003 and other Chuitna Coal Mine area streams represent a more comprehensive restoration effort that includes three-dimensional restoration of the entire channel, including floodplain structure and form, is incomplete. Because the entire 2003 aquifer will be altered to a depth of 300 feet or more
there also needs to be a plan to restore the shallow aquifers that supply phreatic groundwater flow to stream 2003 and possibly to streams 2002 and 2004. There is no mention in the Plan of how pre-mining groundwater flow would be restored to these streams. I have also searched the scientific literature and found numerous papers that document how groundwater flow has been altered after strip-mining restoration but no examples of reclamation efforts that have restored groundwater flow to pre-mining conditions

I have similar concerns with the statement that “Relative examples of this type of project can be found in the reclamation of placer-mined streams.” First, the damage to salmon streams from alluvial placer mining is very different from strip–mining, which may encompass entire drainages and alter both the surface topography and subsurface geology and the aquifers down to several hundred feet. Restoration projects like the USFS projects on Resurrection Creek have attempted to restore both sinuosity and rearing habitat to a stream impacted by placer mining in the early 1900’s by moving and grading spoil piles and providing instream cover. Placer miners channelized the stream and left spoil piles in the flood plain but did not destroy the shallow aquifer that provides groundwater flow to the stream. It appears that the USFS projects have increased rearing habitat for Chinook and coho salmon by connecting formerly isolated channels in mine spoils, but no pre-mining data on fish use is available.

Page 15: The statement that the Chuitna Coal Mine area streams occur in a non-urbanized, pristine watershed where natural functions and processes are intact is true. However, the statement that reclamation design and construction will be largely non-structural in nature with the exception of log jams and where appropriate and grade controls at intervals in active bed reaches is puzzling. First, strip-mining the entire upper stream 2003 drainage and completely altering the surface and subsurface topography and hydrology will have greater effects on fish habitat than urbanization (May et al 1997). Second, construction of a new stream channel will be structural. Structure means a complex entity constructed of many parts, and the Rosgen system consists of characterizing and categorizing stream structure. To construct a functioning stream channel using Rosgen’s system as the basis, the drainage would have to be recontoured and revegetated (which could take decades or longer), a complex new stream channel constructed, and a new shallow aquifer constructed to provide shallow groundwater flow to the new stream. Problems with the use of Rosgen’s system to restore streams are discussed earlier in this report.

Page 16 paragraph 1. It may be possible to design a “stable post mine channel plan form, cross section and profile,” but there is no evidence in the scientific literature that a functioning salmon spawning and rearing stream could be reconstructed after the mining proposed for the stream 2003 drainage is completed. The Plan does not provide any examples of where a fully functioning 17.5 km long salmon spawning and rearing drainage and associated watershed -- or anything on a similar scale -- has been successfully restored after strip mining. An extensive literature search by this reviewer hasn’t turned up any examples either. Without some evidence of previous success, the
entire concept of using Rosen’s classification system to successfully restore a heavily altered drainage is highly questionable.

Page 16. Existing data: The summary of necessary data associated with the stream reclamation is incomplete. To collect information necessary for restoration of the natural hydrological cycles of stream 2003 and the fish populations whose life cycles revolve around seasonal changes in flow and water quality, it is necessary to install stream gauges in strategic stream reaches in stream 2003 and to conduct an instream flow study for a minimum of 5 years or more (Kondolf et al 2000 and Estes and Orsborn 1987). As stated previously, 5 years of flow data is the minimum required by ADNR to grant an instream flow reservation to protect fish habitat to ADF&G (Kline 2009). The number of years of flow measurement would be dependent on knowledge of the fine-scale variation in flows over time and other factors. This has not been done. It is also necessary to measure groundwater flow into stream 2003, because the influx of shallow groundwater is likely the most important factor in overwinter survival of fish and aquatic life (Swales and Levings 1989 and Bennet 2004). Data should be collected over a long enough period of time to determine the full range of daily, seasonal and annual variations in phreatic groundwater flow. This has not been done and this data is not available to design a new functional channel, new shallow aquifers or determine instream flows needs of stream 2002-2004 fish and aquatic life.

Page 20 Beaver activity: Beaver dams affect stream morphology and riparian zones, and provide important habitat for coho salmon and other fishes (Bruner 1989 and Mitchell and Cunjak 2007). The loss of the numerous beaver dams will affect both fish habitat and stream flow in stream 2003. However, this does not appear to be factored into PacRim’s stream restoration plans. Beavers will colonize the upper Stream 2003 drainage only if and when riparian woody deciduous vegetation is fully restored. No estimate is provided of how long reestablishment of woody vegetation may take, but it could be decades or longer. Forty years after peat mining in the Colorado Rockies, sedges and willows that dominated undisturbed sites were largely absent on mined sites (Cooper and MacDonald 2001). Previously reclaimed strip mines in Alaska have been reseeded with grasses and some types of woody vegetation. Monitoring of revegetation at the Usibelli Mine in interior Alaska found that grasses, particularly, boreal red fescue, were the most successful species in part because of the acid soils left after mining (Elliott et al 1986). The floodplain depressions and backwaters PacRim proposes to replace beaver dams and wetlands will not provide the same functions as the 50 beaver dams, 7 lakes, and thousands of acres of wetlands that would be destroyed by mining.

Page 21. Hydrologic and Hydraulic Analysis. Streamflow is the master variable that limits the distribution and abundance of fish species in rivers and streams. Streamflow typically follows a general pattern but may vary hourly, daily, seasonally, yearly and longer. This characteristic pattern of the magnitude, timing, and variability of streamflow defines a river’s flow regime. The life cycles of fishes and other aquatic life are inexorably tied to this flow regime. Alteration of any facet of this natural flow regime can result in significant ecological consequences.
Maintaining natural volumes and patterns of instream flow are essential to preserve fish populations and other aquatic life in the unmined lower reaches of stream 2003. Restoration of premining instream flow patterns to a reconstructed stream 2003 drainage would be extremely difficult. I did not find any examples in the scientific literature of restoration of premining in stream flow patterns and volumes to a similarly altered drainage.

Instream flow is used to identify a specific stream flow in cubic feet per second at a specific location for a defined time, and typically following seasonal variations. Instream flows are the stream flows needed to protect and preserve instream resources and values such as fish, wildlife and recreation (Milhous 1998, Vardas 1999, Estes and Orsborn 1987 and Kondolf et al 2000). Instream flow needs are determined by calculations based on several years of streamflow data and from a network of streamflow gauges placed at key locations within a stream, detailed information on depth, velocity and substrate, and a through understanding to the biology of salmonids. (Estes and Orsborn 1987 and Kondolf et al 2000). However, there is no mention in the Plan of the instream flow needs of fish and aquatic life in the streams likely to be affected by the Chuitna Coal Mine, or any indication in the 2006-2008 Chuitna Coal environmental studies reports that an adequate instream flow study particularly in streams 2002 and 2004 and other Chuitna River tributaries which might be effected by hydrological changes from mining has been conducted. There apparently were some stream gauges in the Chuitna drainage during the 1982-84 studies and the Riverside Technologies Hydrology report indicates that there have been up to 4 gauges in stream 2003. However, there is concern that there weren’t enough gauges and they were not in the right location to determine instream flow requirements in streams 2002, 2003 and 2004 (Mouw, 2009).

PacRim has confirmed that there has been no USGS stream gauge in stream 2003, and the USGS web site does not show that there are presently any stream gauges in the Chuitna River drainage (USGS 2009). The Fish and Wildlife Protection Plan does not indicate there are PacRim gauges in the system either, however, the Riverside Technologies Hydrology Component Baseline indicates that there have been four gauges on stream 2003 with 3 to 16 years of data. According to the Fish and Wildlife Protection Plan PacRim proposes to use USGS flood flow regression equations to calculate flood flows for stream design. This may help design channels that will resist flood flows, but it won’t provide data necessary to maintain fish habitat.

Page 22 Hydrologic and hydraulic analysis: Although the Plan acknowledges the potential for avulsion and subsequent unzipping of a newly constructed channel due to flooding, it does not acknowledge the length of time that this risk will continue or the potential consequences. Revegetation of the mined areas could take a very long time, and during this time the exposed soils will be subject to erosion. The erosion rate of mined watersheds reported by Haigh (2000) was 1.7 mm-yr.-1, or 85 times greater than erosion at an unmined watershed (.02mm-yr.-1). A 10-, 25- or 100-year flood on an unvegetated hillside and floodplain would not only wash out a newly constructed stream channel, but would carry tons of sediment into the stream channel (Martin and Platts 1981 and
Ruediger and Ruediger 1999). This sediment would wash downstream, smothering spawning and rearing areas in unmined sections of stream 2003 (Cordone and Kelley 1960).

Page 30 paragraph 2: LGL’s description of the hyporheic zone as the region below and laterally to the streambed where there is mixing of shallow groundwater and surface water, and its importance in fish spawning and baseflow recharge, is correct. However, the role of shallow groundwater and the hyporheic zone in overwinter survival of fish eggs and fry must also be acknowledged. Unfortunately, the Plan does not explain how the flow of shallow groundwater to the hyporheic zone will be restored after excavation of the existing aquifers down to a depth of several hundred feet below the streambed elevation.

Pages 26-33: Typical construction plans and specifications: The techniques described in this section are all bioengineering techniques which have been used to restore damaged streambanks or relatively short sections of relocated streams. After searching the scientific literature and talking to stream restoration experts, I have not been able to find any examples of where any of the techniques proposed in the Fish and Wildlife Protection Plan have been used to restore the ecological functioning of 17.4 km (or even a smaller scale) of a strip-mined salmon spawning and rearing stream, watershed, and associated aquifers. I also reviewed the references used to support the proposed restoration methodology in the Fish and Wildlife Protection Plan and found only two that might provide information on restoration techniques and successful salmon stream restoration projects in strip-mined areas. These were Rosgen, *Applied River Morphology* (1996) and Leedy et al, *Environmental Reclamation and the Coal Surface Mining Industry* (1987).

Rosgen’s 1996 stream classification system has been widely used to inventory stream channel topography in watersheds, but it is increasingly drawing criticism from hydrologist and engineers for its use in stream restoration (Simon et al 2007, Gillian 1996, Lacombe and Eaton 2003 and PacRim Coal 2007). Some of the problems with using Rosgen’s natural channel design classification system in stream restoration include: (1) alluvial streams are open systems that adjust to altered input of energy and materials, and Rosgen’s form-based system largely ignores this component; (2) C5 channels composed of different bank sediments adjust differently and to different equilibrium morphologies in response to identical disturbances, contradicting the fundamental underpinnings of natural channel design and the reference reach approach which PacRim proposes to use to reconstruct a new stream 2003; and (3) Rosgen’s system fails to integrate and quantify fluvial processes and channel response. This is important because PacRim has not adequately gauged or conducted instream flow studies on any of the streams likely to be impacted by the project (PacRim Coal 2007).

Although, Rosgen’s natural channel design and bioengineering techniques proposed for stream 2003 have apparently not been used to successfully restore salmon spawning streams, they have been regularly used as a cookbook method to restore eroding stream
banks and relocate relatively short sections of streams (Gillian 1996 and Simon et al 2007). One of the difficulties in evaluating the potential effectiveness of stream restoration projects using Rosgen’s methodology and bioengineering techniques in restoring streams and fish habitat is that there have been few quantitative scientific post-project studies. One group of scientists who evaluated the success of stream restoration projects using this methodology found that fewer than half had any pre- or post-project monitoring, and of those that did, most monitored only riparian vegetation and not stream habitat (Moerce and Lambert 2004). Another study, which looked at 23,000 restoration projects, found that 34% did not do any post-project evaluation. Of the 70% who said that their projects were successful, 43% either did not have any success criteria or were unaware of what success criteria are (Rumps et al 2007). PacRim did not reference any studies in the scientific literature documenting the use of Rosgen’s stream classification system to successfully restore a salmon spawning and rearing stream in a deep strip-mined area, and my searches did not reveal any examples either.

I was unable to locate and review the article *Environmental Reclamation and the Coal Mining Industry, National Institute for Urban Wildlife, by D Leedy, L. Adams, G. L. Dove, and G. Jones (1985)*, which is cited in the Plan. The National Institute for Urban Wildlife, which apparently closed in 1995, sponsored research and wrote papers on urban wildlife problems with limited relevance to the Chuitna Coal Project.

*Page 34: Construction Sequencing:* Restoring the flow of phreatic groundwater into the hyporheic zone of stream 2003 is essential to restore fish habitat in stream 2003. The only statement in the Plan which may refer to groundwater restoration is that stockpiled soil will be placed in a “manner to replicate premined strata and compacting conditions. This effort will include replication of subsurface confining zones segregating confined and unconfined aquifers.”

The Plan does not provide any references to support the methodology they have proposed to use to restore groundwater flow or examples of strip mine reclamation projects where groundwater flow was restored to pre-mining conditions by replacing mining tailings or soil. I was also unable to locate any examples in an extensive search of the scientific literature. However, there is a large body of scientific information documenting long-term disruption of both surface and groundwater flow as the result of recently permitted strip mining and reclamation (Bonta 2007, Wilson 1978 and Schwartz and Crowe 1985). Bonta et al (2007) studied the effect of surface mining and reclamation on physical watershed conditions and groundwater hydrology in three watersheds. This study found that mining disturbances in adjacent watersheds affected groundwater levels in the undisturbed watersheds prior to mining. New subsurface flow paths with different characteristics formed during mining and reclamation. Groundwater recovery in the mined upper saturated zone was slow and irregular both temporally and spatially after reclamation. Wilson (1978) found that the impact of a strip mine can extend far beyond its radius of influence at the water table, and mines near regional discharge areas have a more significant effect on the regional system.
Wetlands and Lakes: There are thousands of acres of wetlands and at least seven lakes and ponds that will all be destroyed by the proposed mine, but there is no discussion in the Plan of the long-term consequences of this impact and apparently no plan to restore these wetlands, lakes and ponds after mining. The importance of wetlands to the productivity of salmon streams is well-documented in the scientific literature (Pess et al 2002 and Pollock et al 2004). A recent study of a stream drainage in Southeast Alaska concluded that “Organic nutrients derived from wetlands comprise the bulk of the stream’s water organic nutrient budget on an annual basis.” (Hood et al 2008). The loss of wetlands has been correlated with declines in salmon production (Pess et al 2002 and May et al 1997). Even if the physical structure of stream 2003 could be restored, the currently level of productivity probably cannot be because of the permanent loss of the extensive wetlands in this drainage.

Summary:
The plan for stream restoration presented in the Fish and Wildlife Protection Plan is conceptual and few specifics are provided. The goal of the Plan appears to be to construct a new stream channel on top of mine tailings using stream measurements based on Rosgen’s 1996 stream classification system. Bioengineering techniques would be used to reconstruct the banks. The floodplain would be revegetated at some later time. Because no comprehensive instream flow study has been conducted on stream 2003, the new channel would be designed based on USGS equations and possibly with comparisons with adjacent drainages. During mining, streamflows to stream 2003 would apparently be maintained through a system of bypasses and infiltration galleries. After reconstruction, PacRim expects stream 2003 to evolve to its premining level of productivity.

There are a number of problems with the Plan. First, there is no scientific evidence that stream 2003 could be restored. PacRim does not provide any examples or scientific documentation to support its claim that stream 2003 can be restored to premining productivity. Scientific studies of mines similar to the proposed Chuitna Coal mine concluded that strip mining for coal may affect groundwater flow over a wide area, including adjacent drainages. Even after restoration as required under federal and state regulations, groundwater flow has been altered from premining conditions. An extensive and lengthy search of the scientific literature and discussions with stream restoration and instream flow experts did not yield one example of where a strip-mined salmon spawning and rearing stream and its associated watershed and aquifer have been successfully restored. A list of the databases searched is included in Appendix 1.

Second, there are problems with the proposed stream restoration methodology. The Rosgen stream classification and associated natural stream channel design methods, which are the basis of the proposed PacRim stream restoration plan, has come under increasing criticism from hydrologists and engineers. Some of the problems with using Rosgen’s natural design method in stream restoration include: (1) alluvial streams are open systems that adjust to altered input of energy and materials, and a form-based system largely ignores this component; (2) C5 channels composed of different bank
sediments adjust differently and to different equilibrium morphologies in response to identical disturbances, contradicting the fundamental underpinnings of natural channel design and the reference reach approach which PacRim proposes to use to reconstruct a new stream 2003; and (3) Rosgen’s system fails to integrate and quantify fluvial processes and channel response. This is important because PacRim has not adequately gauged or conducted instream flow studies on any of the streams likely to be impacted by the project (Simon et al 2007, Gillian 1996, Lancombe and Eaton 2003 and PacRim Coal 2007).

Third, the on- and offsite mitigation proposed in the Plan would not compensate for the loss of fish habitat in 17.4 km of stream 2003, alteration of groundwater flow which may also affect streams 2002 and 2004, and the diminishment of stream productivity resulting from the permanent loss of thousands of acres of wetlands. If spawning channels could be successfully constructed, they would offset the loss of spawning habitat only for some species in stream 2003, and only if a corresponding amount of rearing habitat could be created to replace the 17.4 km lost in stream 2003, which seems unlikely. The offsite mitigation proposed, such as the proposal to repair a bridge, restore a section of eroding streambank and remove the Big Lake dam (which has already been removed), is of questionable or no benefit.

Fourth, essential studies of instream flow and the input of groundwater to stream 2003 necessary to support salmon and other aquatic life and reconstruct stream 2003 have not been conducted.

Fifth, there are several thousand acres of riparian and upland wetlands in the stream 2002-2004 drainages that probably provide the bulk of stream 2003’s annual organic nutrient budget that will be destroyed as the result of mining. However, there is no mention of reconstruction of these wetlands or of the functions they currently provide; nor does the Plan contain any plans to reconstruct them.

**H. Conclusions:**

There are serious problems with the data collection methodology, analysis and conclusions of the baseline aquatic resources studies and Fish and Wildlife Protection Plan. These include:

1. There are many problems and questions about the data collection methodology, data analysis and conclusions of the 2006-2008 studies. These are identified and discussed in the comments on each report. In addition, it is problematic to base any conclusions on the limited amount of data that has been collected on key issues such as smolt outmigration, adult escapement, winter fish studies, and smolt production between stream systems. Only one year’s data has been collected on most of these issues,. Because salmon populations have historically fluctuated greatly over a 20 or more year cycle, the few years of data collected is not sufficient to determine the natural range in salmon populations that would be
affected by the Chuitna coal strip mine. For example adult Chinook escapement into the Deshka River, another upper Cook Inlet spawning stream ranged from 57,939 fish in 2004 to 7,533 in 2008. Juvenile salmon and other forms of aquatic life show similar variability. A minimum of 5-10 years of additional study is necessary to determine the natural range of variability in fish populations that would be affected by the Chuitna Coal Mine. A credible mitigation and restoration plan cannot be developed without adequate data.

2. PacRim has not conducted adequate surface and groundwater studies necessary to: accurately map and quantify the seasonal and long term cycles of groundwater input into streams 2002-2004; determine impacts to the Chuitna River drainage from strip-mining and groundwater pumping associated with mining; provide assurances that groundwater flow to unmined portions of streams 2003 and 2004 can be maintained, or: restore essential phreatic groundwater flow to a reconstructed stream 2003.

3. The uninterrupted flow of shallow groundwater to salmonid spawning streams is essential for overwinter survival of eggs and fry. Strip-mining will interrupt this flow and destroy the shallow aquifers that currently provide groundwater to streams. PacRim has not acknowledged this as an issue, provided a plan to restore groundwater flow, or referenced any scientific studies showing where an aquifer supplying phreatic groundwater to a salmon spawning and rearing stream has been successfully restored after strip-mining. An extensive search of the scientific literature returned many examples of how strip-mining has altered groundwater flow during and after mining but no examples of where groundwater has been restored to premining conditions.

4. The failure to determine the genetic makeup of salmonid stocks in streams 2002-2003 and the Chuitna River system is a serious deficiency of the Chuitna Coal environmental studies and proposed monitoring program. Data on genetic characteristics of salmon populations are critical for quantifying the status of local reproductive units (demes) and evolutionary significant units. There is mounting evidence that the individual spawning and rearing streams, such as stream 2003, of coho, sockeye and likely other salmonids may be comprised of demes or small locally interbreeding groups that are genetically adapted to the unique conditions in their natal streams. If these streams and the genetically unique salmon demes that use them are destroyed or blocked by strip-mining as proposed, it is unlikely that these local salmon stocks could be restored to their former level of productivity even if a new stream channel could be successfully constructed.

5. It is probably not possible to reconstruct a new stream with the same level of productivity as the current stream 2003. PacRim has not provided any examples of where a strip-mined salmon spawning and rearing drainage the size of stream 2003 (17.4 km) has been restored to premining productivity. An extensive search of the scientific literature and discussions with stream restoration experts in Alaska and elsewhere has also not produced any examples.

6. There are problems with PacRim’s plan to use Rosgen’s 1996 Applied River Morphology as the basis for stream 2003 reconstruction. Rosgen’s 1996 stream classification system has been widely used to inventory stream channel
topography in watersheds, but it is increasingly drawing criticism from hydrologists and engineers for its use in stream restoration. Some of the problems with using Rosgen’s natural channel design classification system in stream restoration include: alluvial streams are open systems that adjust to altered input of energy and materials and Rosgen’s form-based system largely ignores this component; Rosgen C5 channels composed of different bank sediments adjust differently and to different equilibrium morphologies in response to identical disturbances, contradicting the fundamental underpinnings of natural channel design and the reference reach approach that PacRim proposes to use to reconstruct a new stream 2003; and Rosgen’s system fails to integrate and quantify fluvial processes and channel response. This is important because PacRim has not adequately gauged or conducted instream flow studies on any of the streams likely to be impacted by the project.

7. Even if Stream 2003 could be successfully restored to full physical and ecological function, it may not be possible to restore it to its former level of biological productivity because of the loss of marine derived nutrients (MDN) from salmon carcasses and the permanent removal of all the wetlands in the mine area. Wetlands and MDN are the primary sources of stream nutrients and productivity in salmon streams.

8. The offsite mitigation offered in the plan (i.e. removal of the Big Lake Dam, bridge repair etc.) has little or no potential to offset the loss of fish populations and 17.4 km of high-value fisheries habitat that would be destroyed or altered by mining.

9. There is a good chance that the spawning channels offered as onsite mitigation for the loss would not be successful. Even if these channels were used by spawning adults, any fry produced in spawning channels would probably not survive unless all of the high-value rearing habitat that would be destroyed or blocked by could also be created off site which is very unlikley.

The information provided in the PacRim Coal 2006-2008 Environmental Studies and the summary of the 1980’s studies is inadequate to determine the effect of the proposed Chuitna Coal Mine on fish and fish habitat in the Chuitna drainage. It is also inadequate to develop a mitigation plan and a restoration plan for fish populations and habitat that would be impacted by mining. Additional research is needed. Appendix 2 contains a list of research needs identified during this review.
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Appendix 1: Databases Searched

Academic Search Premier
Alaska and Polar Periodicals
Aquatic Sciences and Fisheries Abstracts
Conference Papers Index
Environmental Sciences and Pollution Management
Fish and Fisheries Worldwide
Science Direct
Water Resources Abstracts
Wildlife and Ecology worldwide
Google Science
Transactions of the American Fisheries Society
Appendix 2: Additional Studies Needed

- 5-10 years of sonar and/or weir counts of adult and salmon smolt in the mainstem Chuitna River and streams 2002-2004.
- Determine if the Chuitna River and streams 2002-2004 are rearing or spawning limited for all species of salmonids.
- Use remote sensing to identify and map groundwater input into streams 2002-2004 and the Chuitna River.
- Determine the relationship between, and the importance of, groundwater and surface water sources in streams 2002, 2003 and 2004 and relate this to the use of available habitat for incubation, rearing, and overwintering.
- A comprehensive study of marine derived nutrients and terrestrial/wetlands nutrient cycling in the Chuitna River drainage and streams 2002-2004.
- A comprehensive study of freshwater and marine survival rates of Chuitna River salmon populations using coded wire tags and other techniques.
- A comprehensive multiyear study of fish movements within and between Chuitna River tributaries using coded wire tags.
- A comprehensive study of factors, including groundwater, affecting overwinter survival of fishes in Streams 2002-2004. Characterize and quantify overwintering habitat.
- Study juvenile salmon rearing and smolt outmigration in the lower Chuitna River and nearshore waters of Cook Inlet.
- Study the effect of weirs on upstream fish movements in streams 2002-2004.
- A comprehensive study of the overwintering behavior and habitat factors (e.g. groundwater, water temperature, instream flow etc.) affecting the overwinter survival of salmonids, other fishes and aquatic life in streams 2002-2004.
- Locate fish spawning and overwintering areas within streams 2002-2004 and the Chuitna River. Measure hyporheic and phreatic groundwater flow and water temperatures in these areas.
- Study the use of the mainstem Chuitna River as rearing habitat by coho and Chinook salmon.
- Conduct a two-year field study to determine the feasibility of using infiltration galleries to restore streamflow to a stream, especially during the winter months.
- Study the rates at which Chuitna salmonids return to natal and non-natal areas to spawn and rear.
- Determine egg to emergent fry and emergent fry to smolt survival rates in streams 2002-2004 and the Chuitna River. Identify and quantify freshwater mortality factors (e.g. predation, freeze-out, etc.).
- Determine the age and size at which Chuitna River coho and Chinook salmon smolt, using coded wire smolt tags and adults recoveries.
- Determine how and when high water events initiate upstream Chinook and coho spawning movements in the Chuitna River drainage.
- Quantify how floods and high water events affect the accuracy of weir counts of upstream and downstream movements of fish in streams 2002-2004.
Dear Commissioner Sullivan:

I am a fisheries habitat consultant with 37 years of experience as a fisheries and habitat biologist and as a Habitat and Restoration Division Regional Supervisor with the Alaska Department of Fish and Game. I am writing in support of the petition to designate the streambeds of anadromous water bodies and riparian areas within the Chuitna River watershed, Alaska, as unsuitable for surface coal mining pursuant to AS. 27.21.260. I support the petition for the following reasons:

1. **The Chuitna River is an important salmon producing system:** Unlike current coal producing areas of Alaska the Chuitna River is located in a productive coastal ecosystem which supports a diversity of fish and wildlife species. Chuitna River supports all five species of pacific salmon as well as Dolly Varden, rainbow trout and whitefish. Chuitna River salmon are harvested by the in river sport fishery, the Northern district commercial fishery, and the Tyonek subsistence fishery. On the west side of Cook Inlet the Chuitna River sport fishery for Chinook salmon is the second only in importance to the Deshka River. Because of its importance the Chuitna River Chinook stock was listed as a stock of management concern by the Alaska Board of Fisheries in 2010 (Helsinger 2010).

2. **Strip mining for coal will destroy the shallow aquifers and interrupt the flow of ground water to anadromous streams in and adjacent to the mined area:** Over the past several years I have conducted an extensive search of the scientific literature but have not found any examples of strip mine reclamation projects where phreatic ground water flow in streams has been restored to premine conditions by replacing mining tailings. However there is a large body of information documenting long term disruption of both surface and ground water flow as the result of recently permitted strip mining and reclamation (Bonta, 2007, Wilson 1978 and Schwartz and Crowe 1985). Bonta et al 2007 studied the effect of surface mining and reclamation on physical watershed conditions and ground water hydrology in three watersheds. This study found that mining disturbances in watersheds affected ground water levels in adjacent undisturbed watersheds prior to mining. Monitoring and testing of groundwater in reclaimed strip coal mines indicate that groundwater is stored in and flows through large voids or conduits in spoil. However, these voids are not always
connected across a mine site (Hawkins 1998, Hawkins and Aljoe 1992). New subsurface flow paths with different characteristics formed during mining and reclamation. Ground water recovery in the mined upper saturated zone was slow and irregular both temporally and spatially after reclamation. Wilson 1978 found that the impact of a strip mine can extend far beyond its radius of influence at the water table, and mines near regional discharge areas have a more significant effect on the regional system.

The uninterrupted flow of shallow ground water to salmonid spawning and streams is essential for successful spawning and survival of eggs and fry. The flow of ground water to streams particularly during the winter is one of the most critical factors in salmonid egg incubation and juvenile overwintering survival (Baxter and McPhail 1999 and Douglas 2006). Mining coal to a depth of 300 feet would remove all the geological structure’s which currently provides shallow ground water to stream 2003 and possibly streams 2002 and 2004.

Two types of ground water influence streams: Hyporheic groundwater, and phreatic ground water (Poole and Berman 2001). Hyporheic groundwater is from the alluvial material which underlies the streambed. It travels downstream along localized pathways before emerging further downstream. Phreatic ground water comes from the catchment’s aquifer and feeds a stream by entering the bottom of the alluvial material and mixing with the hyporheic ground water (USGS 2006). Groundwater from the phreatic aquifer influences stream temperature when it enters the stream. The two way exchange between the alluvial aquifer and the stream channel is perhaps the most important stream temperature buffer (Douglas, 2006).

Figures 1-4 illustrate how ground water is supplied to salmon streams in an undisturbed watershed.
Ground water is critical because it maintains stream base flow and moderates water level fluctuations, particularly in the winter when there is no precipitation. It provides stable temperatures and thermal refugia for fish. It provides water for riparian vegetation which controls bank strength and the rate of erosion (Douglas 2006). It also creates the hyporheic zone (Figure 3).
The hyporheic zone is the region beneath and lateral to a stream bed where there is mixing of shallow ground and surface water. It is an active ecotone between the surface stream and ground water. Exchanges of water, nutrients, and organic matter occur in response to variations in discharge and bed topography and porosity. Upwelling subsurface water supplies stream organisms with nutrients and cool water in the summer and warm water in the winter. Down welling stream water provides dissolved oxygen and organic matter to microbes, and invertebrates, in the stream bottom (Boulton, et al 1998). Upwelling ground water is vital to protect salmonids and other cold water fishes from water temperatures which exceed their thermal tolerance in the summer (Hayes 2009). Ground water provides over-wintering habitat free of subsurface ice protect fish eggs, larvae, and juvenile fishes from freezing in the winter (Power et al 1999).

The hyporheic zone is an area of intense biochemical activity. Biogeochemical processes within the upper few centimeters of sediments have a profound effect on the chemistry of ground water and surface water which mix in that area. Biogeochemical process is the partitioning and cycling of chemical elements and compounds between the living and non living parts of a stream. The highly interactive nature of physical, chemical and biological processes in the hyporheic zone play a central role in the functioning of stream ecosystems (Malcolm et al 2003).
To restore fish habitat in these streams after mining it, it would be necessary to restore the same quality and quantity of ground water. To successfully reconstruct a new stream that is as productive as mined streams, it would be necessary to reconstruct a new shallow aquifer to provide the same amount of phreatic and hyporheic flow, the same seasonal flow patterns and same quality (temperature, pH, dissolved elements, dissolved solids etc.) of ground water present prior to mining. I conducted an extensive search of the scientific literature to find examples of restoration of salmon streams after the type of strip mining proposed for the Chuitna River drainage. I also consulted with experts who have been involved in salmon habitat and strip mine restoration in Alaska and the continental United States. The search found many examples of how strip mining has dramatically altered local and regional ground water flow during and after mining, but no references to any scientific studies of mines where the aquifer’s supplying phreatic ground water to the hyporheic zone of a salmon spawning and rearing stream has been successfully restored to premining productivity after strip mining. Most experts do not believe that it is possible to reconstruct a functioning shallow aquifer for an anadromous streams system in a deep mined system with any degree of confidence that it would work. Attempts to restore ground water flow to mined stream would be further hampered by the fact that the very complex geology of the Chuitna River drainage and how these shallow aquifers function is poorly understood except that ground water from these aquifers up well’s at certain points in these streams and currently supports salmon spawning, rearing and overwintering.

3. Strip mining will result in the long loss of marine derived nutrients and organic carbon essential to stream productivity: Even if mined anadromous stream channel’s in the Chuitna River drainage could be successfully reconstructed to full physical function, it is unlikely these streams could be restored to their former level of biological productivity because of the loss of marine derived nutrients (MDN) from salmon carcasses in the mined areas and the loss of organic carbon from the removal of all of the wetlands in the mine area. Significant loss of stream productivity from premining conditions has been documented in studies of streams in reclaimed stripmines. Matter and Ney (1981) found that “benthic invertebrate and fish populations were significantly lower in abundance in the reclaimed mine streams than in the reference stream and showed less taxonomic richness and stability: they were similar in these respects to the biota of unreclaimed mine streams.”

Wetlands and MDN from salmon carcasses are the primary sources of stream nutrients and productivity in salmon streams. There is a large body of scientific literature showing that Pacific salmon are the major vehicle transporting marine nutrients across ecosystem boundaries from marine to freshwater and terrestrial ecosystems. Nutrients from salmon eggs and carcasses play a major role in the productivity of both freshwater and riparian ecosystems and in perpetuating future salmon runs. Most fisheries scientists and progressive fisheries managers have concluded that stream ecosystem health benefits from having the largest number of spawners possible which in turn produces a large number of carcasses (WDFW 1997). The eggs and carcasses from these spawning salmon provide an essential source of food for rearing salmon and other fishes which concentrate in these areas. Nutrients from decaying carcasses also provide food and nutrients for insects such as chironomids which are the major food source for salmonids during the rest of the growing
season. Bilby, et al 1996 and 1998 found that benthic algae, invertebrates and fish in salmon streams were significantly enriched with both marine carbon and nitrogen. The average contribution of marine nitrogen ranged from 11% for invertebrate predators to 31% for juvenile Coho. The highest percentage of marine nitrogen was 46% for adult cutthroat trout and 61% for age 1 plus steelhead. The same researchers also found that the growth rate of juvenile coho doubled after adults spawned in the stream, where as in a nearby stream without spawning salmon juvenile steelhead showed no increase in growth rate during the same time period. This phenomenon is so important that fisheries scientists recommend that escapement goals should be designed to produce “nutrient capital” within watershed that will help support the next generation of fish.

During mining, salmon will be excluded from the middle and upper portions of Stream 2003 where most spawning and rearing occurs for a long period of time. The “nutrient capital” built up over hundreds of years would be lost when the upper portion of the stream 2003 drainage is removed through mining. Diminishing or eliminating salmon production (e.g. eggs and carcasses) from a stream due to natural or anthropomorphic causes, such as strip mining may be self perpetuating. Without necessary nutrients from salmon eggs and carcasses, remaining downstream stream 2003 stocks are likely to decline further. A reconstructed stream drainage without nutrients from salmon carcasses is not likely to be productive (Bilby et al 1996 and Larkin and Slaney 1997).

The concurrent loss of most of the wetlands, which are the other major source of stream nutrients in the stream 2003 drainage headwaters, will further reduce stream productivity (Hood et al 2008, Meyer et al 2003, and Nagorski et al 2007). As previously stated the productivity of a salmon stream is based on marine derived nutrients (MDN) from salmon carcasses and the flow of organic matter, nutrients, and the consistent flow of high quality ground and surface water from its drainage basin (Piccolo et al 2009, Mathisen et al 1998, and Schlosser 1991). Wetlands have been identified as a major terrestrial contributor of organic matter and nutrients to salmon streams (Hood et al 2008, Pess et al 2002, and Nagorski et al 2007). A recent study in S.E. Alaska concluded that “Organic nutrients derived from wetlands comprise the bulk of the stream water organic nutrient budget on an annual basis” (Hood et al 2008). The loss of wetlands has been correlated with declines in salmon production (Pess, et al 2002). All of the wetlands, which currently comprise 43% of the proposed mine area and provide ground water discharge, ground water recharge, and carbon export/food chain support to streams 2003 and to a degree 2002, and 2004, will be destroyed by mining. Even if stream 2003 could be reconstructed, the loss of both of the major sources of stream productivity would make it very difficult if not impossible to restore it to its former level of productivity.

There is nothing in the scientific literature to indicate that it is technically or economically feasible to reconstruct thousands of acres of replacement wetlands on top of porous mine tailings in the Chuitna River drainage. Unless both the amount and function of current wetlands can be replaced, stream productivity and fisheries production can not be restored to premining levels of productivity. The National Academy of Science recommends not destroying filling fens and bogs, both found in the Chuitna claims area, because they are
“difficult or impossible to restore” (National Academy of Science 2001). For certain types of wetlands such as peat bogs which grow at a rate of less than 1mm annually, replacement is not feasible within geological time. Wetlands whether natural or constructed exist because of the presence of surface or near surface water. The extensive wetlands in the Chuitna River drainage exist in part because weathered volcanic ash a few feet below the surface forms clay like impermeable layer which holds water. Deeper layers of compacted ash act as an aquitard confining the water table below it and forcing seeps and springs out of the hillsides and into adjacent drainages. Once the existing wetlands and the impermeable soils that currently maintain these wetlands are removed by mining there is nothing to provide a base for construction of new wetlands. There are no studies in the scientific literature which indicates that wetlands have been restored on coal mine spoils on the scale which would be required in the Chuitna River drainage. The risk of failure for many wetlands restoration projects is high, particularly in Alaska where no projects of this type have been documented (Kusler, 2004 and National Academy of Sciences, 2001).

4. Mining will adversely affect water quality for fish and aquatic life: Information provided by Pac rim contractors indicates that water quality will change as a result of mining in the Chuitna River drainage. Potential water quality changes include lower Ph, higher turbidity, and releases of heavy metals such as copper. Fish and their food organisms in the Chuitna River drainage have adapted to the unique water quality conditions present in the Chuitna River and its tributaries over thousands of years. Water quality is defined by dissolved elements, marine derived and terrestrial nutrients, and physical factors such as temperature, pH, conductivity, and turbidity. Anadromous species such as salmon, trout, and whitefish also depend on subtle chemical clues present in surface waters in to locate both their natal streams, and spawning locations within tributaries.

Surface water chemistry will be altered by pumping water out of the pit to allow mining and rerouting surface water away from the pit area and into streams. Data collected by Pac Rim contractors indicates that one or more of the aquifers in the mine areas contains elevated levels of copper, zinc, iron, aluminum, manganese and lead. Zinc and manganese levels in ground water within the proposed Chuitna mine area are approximately 4 times and aluminum 20 times greater than average surface water levels in stream within the proposed Chuitna mine area. All of these metals are toxic to fish and aquatic life at levels in the part per billion to part per million ranges. Aluminum interferes with phosphorus metabolism in plants which form the basis of the aquatic food chain in streams. It also precipitates on fish gill membranes inhibiting exchange of oxygen and carbon dioxide which results in asphyxiation. Copper is toxic to rainbow trout at 1.4 parts per billion, and elevated levels (5-20 ppb.) destroys the olfactory organs which anadromous fish use to locate prey and spawning streams. Zinc is toxic in the part per billion range and accumulates in and damages gills, liver, and kidneys. Copper, zinc and lead bioconcentrate (build up to high levels over time) in aquatic organisms. Copper and zinc also act synergistically in the aquatic environment so that the toxicity of the combination is greater than the individual elements.

Toxicity of these heavy metals is greater at reduced pH levels. Because both bog and upland soils in the mine area are acidic with pH values ranging from 3.2 to 6.1 there is significant
potential for acid run off from exposed soils to lower the pH of surface waters during mining. Reductions in pH result in reduced stream productivity and the health of juvenile anadromous fish. It is important to note that Pac Rim has applied for “site specific criteria” for copper, zinc, aluminum, lead, manganese, and iron which would allow them to discharge these metals in greater concentrations than natural levels in Chuitna River tributaries and state water quality regulations allow.

In addition to the general debilitating effect of degrading water quality as a result of mining and exemptions for state water quality there is an additional problem that must be considered. Mining operations in Alaska have frequently violated their water quality permits. For example the Red Dog Mine has been cited for over a thousand water quality violations to date.

5. Loss of genetically unique salmonid stocks and their habitat: The genetic makeup of salmonid stocks in streams 2002-2004 may be a serious impediment to successful restoration of the salmonid ecosystem in mined streams. There is mounting evidence from Alaska and elsewhere that Coho, Chinook, sockeye and likely other salmonids with a high level of fidelity to individual spawning and rearing streams, are comprised of demes or small locally interbreeding groups (demes) that are genetically adapted to the unique ground and surface water flow, temperature, and water quality conditions in their natal streams, or at specific locations within their natal streams. If these streams or portions of them are destroyed by strip mining as proposed, it is very unlikely that the unique stream flow, temperature, and water quality conditions which currently exist in these streams and these salmonids are adapted to, can be recreated.

Similarly if genetically unique salmon stocks which are adapted to spawning and rearing in these headwaters streams are blocked from using former habitat for many years to accommodate mining, these demes may die out rather than spawn in another location. This phenomenon has been observed in sockeye salmon which, when blocked from accessing traditional upstream spawning areas by beaver dams or man made structures, die without spawning. Because of these adaptations to the unique physical, water quality, and stream flow conditions currently found in Chuitna River tributaries it may not be possible to restore these tributaries to their former level of productivity even if a stable stream channel could be reconstructed.

6. Past stream stabilization and stream bank restoration projects are not analogous to watershed reconstruction in the Chuitna River drainage: I caution ADNR decision makers not to accept claims that reconstruction of strip mined salmon streams, their watersheds and associated aquifers are feasible based on anecdotal reports of reclamation of placer mined streams, stream bank restoration, or return of streams to old channels such as Moose Creek in the Matanuska River drainage. The damage to salmon streams from alluvial placer mining and is very different from strip mining, which may encompass entire drainages and alter both the surface topography, subsurface geology and the aquifers down to several hundred feet. The objective of most of these stream projects has been to stabilize a short section of an existing stream channel and not reconstruct an entire drainage, stream channel and aquifer.
Although there may have been some benefits to fish, I have not been able to find any reports or scientific studies documenting that these stream relocation or stabilization projects have benefitted fish. Most of these projects such as the USFS projects on Resurrection Creek have attempted to restore both sinuosity and rearing habitat to a stream impacted by placer mining in the early 1900’s by moving and grading spoil piles and providing instream cover. Placer miners channelized the stream and left spoil piles in the flood plain but did not destroy the shallow aquifer that provides ground water flow to the stream. It appears that the USFS projects have increased rearing habitat for Chinook and Coho salmon by connecting formerly isolated channels in mine spoils, but no data has been made available to document this. Similarly, it is likely that the rerouting of Moose Creek back into its original channel has provided access to additional upstream spawning and rearing habitat for salmon in previously inaccessible upstream waters but no scientific data is provided to support this. However, this project like the others does not provide any indication of the likelihood of success in completely reconstructing a salmon stream, recreating the existing water chemistry, recontouring and revegetating its drainage, reconstructing all of its wetlands and rebuilding its aquifers from basement sediments on up in the Chuitna River drainage.

7. A great deal of new information that raises questions about the feasibility of restoring anadromous within the Chuitna River drainage to their premining level of productivity has become available since the 1990 Diamond Chuitna Coal Project Final Environmental Impact Statement. When the Diamond Chuitna Coal Project Final Environmental Impact Statement was completed in 1990 very little was known about the physical, chemical and biological components of salmon habitat, and the function of in stream flow and ground water, marine derived nutrients, and wetlands in the productivity of salmon streams. Studies of salmon salmon genetics, the effects of mining on salmon streams, and the restoration of salmon streams were in their infancy. The impetus for much of this research was the continued decline of salmon stocks due to human activities. Since 1990 a great deal of scientific research on these subjects has been completed and information has become available. This information support the conclusion that strip mining for coal will severely impact current anadromous waters in the Chuitna River drainage and that it is very unlikely that these waters could be restored to their premining level of productivity

Thank you for your consideration of my request that you grant the Petition to Designate the Streambeds of Anadromous Water Bodies and Riparian Areas within the Chuitna River Watershed, Alaska. as Unsuitable for Surface Coal Mining Pursuant to AS. 27.21.260. If you have any questions you can contact me at the address shown above.

Sincerely,

Lance Trasky
Literature Cited:


For citations not listed here please refer to my 2009 report, Report on Chuitna Coal Project Aquatic Studies and Fish and Wildlife Protection Plan which has been previously provided to ADNR
Seasonal persistence of marine-derived nutrients in south-central Alaskan salmon streams

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Abstract. Spawning salmon deliver annual pulses of marine-derived nutrients (MDN) to riverine ecosystems around the Pacific Rim, leading to increased growth and condition in aquatic and riparian biota. The influence of pulsed resources may last for extended periods of time when recipient food webs have effective storage mechanisms, yet few studies have tracked the seasonal persistence of MDN. With this as our goal, we sampled stream water chemistry and selected stream and riparian biota spring through fall at 18 stations (in six watersheds) that vary widely in spawner abundance and at nine stations (in three watersheds) where salmon runs were blocked by waterfalls. We then developed regression models that related dissolved nutrient concentrations and biochemical measures of MDN assimilation to localized spawner density across these 27 stations. Stream water ammonium-N and orthophosphate-P concentrations increased with spawner density during the summer salmon runs, but responses did not persist into the following fall. The effect of spawner density on δ15N in generalist macroinvertebrates and three independent MDN metrics (δ15N, δ34S, and α3:06 fatty acids) in juvenile Dolly Varden (Salvelinus malma) was positive and similar during each season, indicating that MDN levels in biota increased with spawner abundance and were maintained for at least nine months after inputs. Delta 15N in a riparian plant, horsetail (Equisetum fluviatile), and scraper macroinvertebrates did not vary with spawner density in any season, suggesting a lack of MDN assimilation by these lower trophic levels. Our results demonstrate the ready assimilation of MDN by generalist consumers and the persistence of this pulsed subsidy in these organisms through the winter and into the next growing season.

Key words: Alaska; aquatic macroinvertebrate; Dolly Varden (Salvelinus malma); fatty acid; horsetail (Equisetum fluviatile); Kenai Peninsula; marine-derived nutrients; seasonal persistence; stable isotopes.

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INTRODUCTION

Organisms and material routinely move between habitats, and many of these subsidies are marked by short, intermittent periods of abundance (Polis et al. 1997, Yang et al. 2008). These pulsed subsidies—exemplified by events such as insect mass emergence (Williams et al. 1993) and mast fruiting in plants (Ostfeld et al. 1996)—are readily exploited by generalist consumers due to their ability to switch prey (Ostfeld and Keesing 2000, Sears et al. 2004) and can generate bottom-up perturbations that influence population dynamics and community structure across multiple trophic levels (Yang et al. 2008). When recipient food webs have effective storage mechanisms, the influence of pulsed resources may last far longer than the availability of the resource (Yang et al. 2008).

Annual pulses of marine-derived nutrients (MDN), conveyed to freshwater ecosystems by millions of spawning, semelparous Pacific salmon (Oncorhynchus spp.) in the form of eggs, excreta, carcasses, and emergent fry, are an ecologically important energy and nutrient subsidy to stream and riparian ecosystems (Gende et al. 2002, Naiman et al. 2002, Schindler et al. 2003). Where salmon returns remain abundant, MDN subsidies can have ecosystem-wide effects. Dissolved MDN, excreted by live salmon and liberated from decomposing carcasses, can boost periphyton biomass (Wipfli et al. 1998, 1999, Johnston et al. 2004) and leaf litter decomposition (Claeson et al. 2006). The presence of salmon carcasses enhances growth and development rates for taxa that scavenge carcass material (Minakawa et al. 2002, Walter et al. 2006) and is often associated with increased abundance and biomass of aquatic macroinvertebrates (e.g., Wipfli et al. 1998, 1999, Minakawa and Gara 1999, Claeson et al. 2006, Lessard and Merritt 2006). Substrate disturbance during salmon spawning, however, can offset these effects and reduce overall periphyton and macroinvertebrate biomass (Moore and Schindler 2008, Verspoor et al. 2010), especially in streams with fine sediments (Janetski et al. 2009). Growth and energy storage among stream-dwelling fishes is increased by MDN (Bilby et al. 1996, Wipfli et al. 2003, Heintz et al. 2004, Rinella et al. 2012) and the direct consumption of eggs and carcass material appears to be more important than bottom-up pathways for conveying MDN benefits (Scheuerell et al. 2007, Denton et al. 2009, Armstrong et al. 2010). MDN is transferred to the riparian environment by hyporheic processes, flooding, and terrestrial scavengers (Cederholm et al. 1989, Ben-David et al. 1998, Hilderbrand et al. 1999, O’Keefe and Edwards 2002, Quinn et al. 2009), where it enriches riparian soils (Bartz and Naiman 2005, Drake et al. 2005). Riparian vegetation can derive a substantial proportion of nitrogen from this pool (Bilby et al. 2003, Reimchen et al. 2003), which may lead to enhanced growth rates (Helfield and Naiman 2001, 2002; but see Kirchhoff 2003 and Helfield and Naiman 2003).

MDN’s ecological importance is demonstrated in cases where the supply has been disrupted, such as the Columbia River basin where dams and habitat degradation have led to the prolonged depression of salmon stocks. Density-dependent mortality has been documented among juvenile Chinook salmon (O. tshawytscha), despite the fact that populations have been reduced to a fraction of historic levels, suggesting that nutrient deficits have lowered the carrying capacity of the Columbia River basin (Achord et al. 2003, Scheuerell et al. 2005). Recognizing the importance of MDN to salmon production, fisheries managers are adapting strategies to restore nutrient supplies to salmon-producing ecosystems (Stockner 2003, Michael 2005).

While the ecological importance of MDN has been well established, the persistence of this pulsed subsidy in riverine ecosystems has not been adequately investigated nor has a clear picture emerged from the literature. Studies tracking persistence have generally shown MDN levels to diminish in primary producers (Bilby et al. 1996, Claeson et al. 2006, Holtgrieve et al. 2010, but see Verspoor et al. 2010), macroinvertebrates (Bilby et al. 1996, Claeson et al. 2006, Walter et al. 2006, Honea and Gara 2009), and salmonid fishes (Bilby et al. 1996, Reichert et al. 2008, but see Rinella et al. 2012) over the months following salmon spawning. Additional studies that track MDN across multiple trophic levels and from a range of physiographical settings will help ecologists come to a general understanding of the factors that regulate MDN persistence in salmon streams. Studies that
rely on spatial variation in spawner abundance across multiple watersheds (e.g., Holtgrieve et al. 2010, Verspoor et al. 2010, 2011, Rinella et al. 2012) are particularly useful because they avoid the artificiality sometimes present in manipulative studies while allowing broader inferences to be drawn from the data.

The goal of this research was to better understand the seasonal persistence of MDN resources in stream food webs. To accomplish this, we examined the effect of a 27-station (in nine watersheds) gradient in spawner density on dissolved nutrient concentrations and measures of MDN assimilation in aquatic and riparian biota across three seasons. We modeled the effects of spawner density during summer and fall to examine MDN presence during and shortly after the spawning season, and during spring to indicate overwinter persistence of MDN from the previous year’s spawning run. For biota, we focused our efforts on stream-resident Dolly Varden (Salvelinus malma), a generalist predator, due to their near ubiquitous distribution in coastal Alaskan streams; selected aquatic macroinvertebrates (both primary consumers and generalists) common in Alaska streams; and a widespread riparian plant, horse-tail (Equisetum fluviatile).

METHODS

Study sites

We collected field data at three stations in each of three watersheds within three geomorphically distinct regions on the Kenai Peninsula, Alaska (N = 27 stations; Fig. 1) during 2005. Streams within a given region were in relatively close proximity and were geomorphologically similar to the extent possible (i.e., similar basin area, elevation, channel slope). Each region contained two salmon streams where salmon escapement (i.e., the number of fish that escape fisheries and return to spawn) was monitored by the Alaska Department of Fish and Game (ADF&G) and one salmon-free reference stream where spawning runs were blocked by waterfalls (Table 1).

Cooper Landing area streams.—The Cooper Landing study streams are within the Kenai River basin, the Kenai Peninsula’s largest watershed, which supports substantial commercial, subsistence, and sport fisheries. Sockeye are the dominant salmon, and their young rear in the watershed’s many low-elevation, accessible lakes. Study streams consisted of the Russian River and Quartz Creek as salmon-bearing streams and Juneau Creek as a salmon-free reference (Table 1). These streams are in the Chugach–St. Elias Mountains ecoregion (Nowacki et al. 2001) that has a continental climate with approximately 64 cm of annual precipitation (Brabets et al. 1999). Underlying geology is primarily metamorphic, volcanic, and igneous rock (Brabets et al. 1999) and, as such, these streams had relatively low concentrations of primary nutrients. These streams have gently sloped mainstem channels that drain mixed spruce (Picea spp.) and birch (Betula papyrifera) forest with steep tributaries that drain alpine basins.

The Russian River system receives two spawning runs of sockeye salmon (O. nerka) each year. The early run, which averages 49,000 fish, arrives during the second half of June and the late run, which averages 87,000 fish, arrives from mid-July to mid-August (1996–2005 data; ADF&G 2006). The Russian River also receives much smaller numbers of Chinook and coho (O. kisutch) salmon. Quartz Creek typically receives between 1000 and 20,000 sockeye salmon that spawn from mid to late August and a small number of Chinook salmon (<100 fish) that spawn prior to the sockeye salmon (ADF&G, unpublished data). Juneau Creek has a waterfall ~3 km upstream of its confluence with the Kenai River which blocks salmon access to most of the basin, and all sampling stations on Juneau Creek were located above this barrier.

Homer area streams.—The Homer-area streams consisted of the North Fork Anchor River and the South Fork Anchor River as salmon-bearing streams and Happy Creek as a salmon-free reference (Table 1). This area is in the Cook Inlet Basin ecoregion (Nowacki et al. 2001) and has a climate transitional between maritime and continental with approximately 57 cm annual precipitation (Brabets et al. 1999). Streams in this area drain extensive unconsolidated glacial deposits and proglacial lake sediments (Selkregg 1974), which results in relatively high ambient nutrient concentrations. The uplands consist of rolling white spruce (Picea glauca) forest while riparian vegetation is typically mixed cottonwood (Populus spp.) and spruce along the lower alluvial...
stream reaches, giving way to poorly drained soils dominated by willow (*Salix* spp.) and herbaceous plants in the upper reaches. There are no significant lakes in this area, but wetlands comprise about 20% of the watershed (Mauger 2005).

On average, the Anchor River system receives runs of about 8000 of each Chinook and coho salmon plus around 2700 pink salmon (*O. gorbuscha*) (2004–2010 average; Szarzi et al. 2010). Happy Creek has no anadromous runs due to an impassible waterfall at tidewater.

Table 1. Physical characteristics and total spawner biomass for the nine study streams in three regions on the Kenai Peninsula, Alaska.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Watershed area (km²)</th>
<th>Length of salmon spawning (km)</th>
<th>Latitude (WGS84)</th>
<th>Longitude (WGS84)</th>
<th>Spawner biomass (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2004</td>
</tr>
<tr>
<td>Cooper Landing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juneau</td>
<td>146</td>
<td>0</td>
<td>−149.8961</td>
<td>60.5203</td>
<td>0</td>
</tr>
<tr>
<td>Quartz</td>
<td>322</td>
<td>19</td>
<td>−149.6852</td>
<td>60.5059</td>
<td>31</td>
</tr>
<tr>
<td>Russian</td>
<td>166</td>
<td>26</td>
<td>−149.9749</td>
<td>60.4782</td>
<td>382</td>
</tr>
<tr>
<td>Homer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happy</td>
<td>29</td>
<td>0</td>
<td>−151.7396</td>
<td>59.9359</td>
<td>0</td>
</tr>
<tr>
<td>N.F. Anchor</td>
<td>180</td>
<td>27</td>
<td>−151.8265</td>
<td>59.7766</td>
<td>18</td>
</tr>
<tr>
<td>S.F. Anchor</td>
<td>373</td>
<td>72</td>
<td>−151.8289</td>
<td>59.7711</td>
<td>97</td>
</tr>
<tr>
<td>Seldovia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China Poot</td>
<td>28</td>
<td>0</td>
<td>−151.1948</td>
<td>59.5413</td>
<td>0</td>
</tr>
<tr>
<td>Barabara</td>
<td>56</td>
<td>11</td>
<td>−151.6426</td>
<td>59.4753</td>
<td>8</td>
</tr>
<tr>
<td>Humpy</td>
<td>28</td>
<td>6</td>
<td>−151.1434</td>
<td>59.6576</td>
<td>49</td>
</tr>
</tbody>
</table>

Note: MT = metric tons.
Seldovia area streams.—In the Seldovia region, we sampled Humpy and Barabara creeks in addition to China Poot Creek as a salmon-free reference (Table 1). This area is in the Gulf of Alaska Coast ecoregion (Nowacki et al. 2001) and has a maritime climate with approximately 140 cm annual precipitation (Brabets et al. 1999). Underlying geology is primarily metamorphic, volcanic, and igneous rock (Brabets et al. 1999), giving these streams relatively low concentrations of primary nutrients. Streams in this area drain short, steep watersheds that flow directly into Kachemak Bay. Vegetation is dominated by white spruce and Sitka spruce (P. sitchensis), giving way to extensive alder (Alnus spp.) stands at higher elevations.

Humpy Creek receives a small run of chum salmon (O. keta) that spawn in early August and a sizeable run of pink salmon that spawn during mid to late August. Barabara Creek receives a run of pink salmon that spawn during late August. Average pink salmon escapement to Humpy and Barabara creeks based on ADF&G ground surveys is 47,300 and 4900 fish, respectively (1960–2006 average; Hammarstrom and Ford 2008). Salmon runs to China Poot Creek are blocked by a waterfall approximately 2 km above tidewater.

Field sampling

We established three sampling stations within each of the nine watersheds: one near the stream mouth, one near the geographic middle of the mainstem, and one in the upper reaches. At each station, we conducted biological sampling over a reach of approximately 150 m. Due to the lack of road access in most of the watersheds, we chose the exact sampling locations based on ease of hiking or floatplane access.

We sampled each stream in spring prior to the initiation of spawning runs, during the peak summer spawning period, and (for Cooper Landing and Homer area streams) again during the fall. Because each region differed in the dominant spawning salmon species, we shifted summer and fall sampling to ensure that summer sampling coincided with peak salmon spawning and that fall sampling coincided with a period of post-spawn carcass decomposition (Table 2). During station visits, we collected water samples for analysis of dissolved nutrient concentrations (Table 3) and collected samples of horsetail, select macroinvertebrate taxa, and Dolly Varden for biochemical analyses of MDN assimilation.

We chose the perennial horsetail as a riparian plant because it grew at or near the wetted margin of every study reach (Table 4). We gathered five individual horsetail stems from locations dispersed over the sampling reach; all stems were growing in shallow water or in saturated soil close to the stream margin.

For macroinvertebrates, we collected dominant taxa of immature aquatic insects representing two functional feeding groups, taking care to collect the same taxa across all streams in a given sampling event when possible. We collected scrapers (i.e., primary consumers; typically the caddidfly Glossosoma sp. or the mayfly Drunella doddsi) and generalists (limnephilid caddiflies Ecclisomyia conspersa and Psychoglypha sp. or the stonefly Pteronarcella sp.). These feeding groups were found at most stations (Table 4). We collected scrapers by hand picking them from cobbles in riffle habitats and generalists by kick netting in depositional areas.

We chose Dolly Varden as our focal fish species because they are widely distributed in the study area, occurring in salmon streams and above barriers in many salmon-free streams. We collected one to eight juvenile Dolly Varden per station per sampling event (Table 5) using minnow traps baited with salmon roe. The salmon roe was contained in perforated plastic bags to prevent consumption by trapped fish. When excess fish were captured, we retained individuals that spanned the size range observed

---

Table 2. Sampling dates for the three Kenai Peninsula study regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper Landing</td>
<td>6/1–6/16</td>
<td>8/20–9/9</td>
<td>10/2–10/14</td>
</tr>
<tr>
<td>Homer</td>
<td>5/12–5/28</td>
<td>8/10–8/23</td>
<td>10/7–10/26</td>
</tr>
<tr>
<td>Seldovia</td>
<td>6/22–7/8</td>
<td>9/8–9/21</td>
<td>no samples</td>
</tr>
</tbody>
</table>
at that station. Across all streams, fork length ranged from approximately 50 to 150 mm.

We were unable to collect all the samples we targeted. Seldovia area streams are accessible only by boat or aircraft and inclement weather prevented us from accessing this area during the fall. We did not collect horsetail during the fall sampling period because it had senesced and we expected this would alter the nitrogen isotopic composition. We found no Dolly Varden in China Poot Creek. Additional missing data are due to unavailability of some taxa at the time of sampling, missed holding times, and other logistical problems (Tables 3, 4, and 5).

We filtered water samples in the field with a syringe and 0.45-μm filter (Whatman, Maidstone, Kent, UK) and kept them cool until delivery to the lab. We kept all biological samples on ice or on liquid nitrogen in cases where field storage time exceeded several hours; in the lab, we stored samples in a −70°C ultra-cold freezer until processed. We analyzed Dolly Varden and horsetail stems individually but, because of mass constraints for analytical measurements, we analyzed composite samples of at least 10 individual macroinvertebrates. We thawed the Dolly Varden long enough to homogenize and split into subsamples for stable isotope and fatty acid analyses. All samples for stable isotope analyses (i.e., fish homogenate, horsetail stems, macroinvertebrate composites) were first oven dried (48 hours at 65°C) and pulverized. Fish homogenate for fatty acid analysis was re-frozen (−70°C) until analysis.

#### Laboratory analyses

We used three separate biochemical measures of MDN assimilation. We measured nitrogen stable isotopes (δ15N) in horsetail, scraper and generalist macroinvertebrates, and Dolly Varden, and additionally measured sulfur stable isotopes (δ34S) and fatty acid composition in Dolly Varden. Delta 15N has been used extensively to measure incorporation of MDN in freshwater food webs (e.g., Kline et al. 1990, Bilby et al. 1996, Chaloner et al. 2002, Scheuerell et al. 2007). Delta 15N in adult salmon (typically 10–15%; reviewed in Johnson and Schindler 2009) is enriched

### Table 3. Dissolved nutrient concentrations from the 27 sampling stations across three seasons.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Station</th>
<th>NH4-N (μg/L)</th>
<th>PO4-P (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spring</td>
<td>Summer</td>
</tr>
<tr>
<td>Juneau (salmon-free)</td>
<td>lower</td>
<td>4.51</td>
<td>4.78</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>2.79</td>
<td>3.57</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>1.28</td>
<td>2.44</td>
</tr>
<tr>
<td>Quartz</td>
<td>lower</td>
<td>0.94</td>
<td>39.95</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>0.30</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>0.52</td>
<td>4.15</td>
</tr>
<tr>
<td>Russian</td>
<td>lower</td>
<td>5.10</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>2.97</td>
<td>19.64</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>6.37</td>
<td>3.71</td>
</tr>
<tr>
<td>Happy (salmon-free)</td>
<td>lower</td>
<td>10.80</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>10.29</td>
<td>28.92</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>7.92</td>
<td>12.50</td>
</tr>
<tr>
<td>N.F. Anchor</td>
<td>lower</td>
<td>0.09</td>
<td>5.47</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>12.66</td>
<td>19.38</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>1.14</td>
<td>5.29</td>
</tr>
<tr>
<td>S.F. Anchor</td>
<td>lower</td>
<td>5.25</td>
<td>16.09</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>1.40</td>
<td>27.54</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>20.01</td>
<td>2.44</td>
</tr>
<tr>
<td>China Poot (salmon-free)</td>
<td>lower</td>
<td>1.16</td>
<td>4.84</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>0.70</td>
<td>32.99</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>0.11</td>
<td>1.86</td>
</tr>
<tr>
<td>Barabara</td>
<td>lower</td>
<td>1.93</td>
<td>7.19</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>0.10</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>1.49</td>
<td>3.45</td>
</tr>
<tr>
<td>Humpy</td>
<td>lower</td>
<td>1.47</td>
<td>1542.21</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>0.10</td>
<td>487.93</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>3.38</td>
<td>...</td>
</tr>
</tbody>
</table>

Notes: N = 1 per station and season. Seldovia-area streams were not sampled during the fall; other missing data did not meet laboratory holding times and were not analyzed.
relative to freshwater sources (e.g., 0 to 9, depending on trophic level; Kline et al. 1990), creating an isotopic disparity that can be used to measure the relative contribution of marine and freshwater nutrient pools. Isotopic differences also exist between marine and freshwater sulfur (sulfate and organic sulfur) and we expected that $\delta^{34}S$ would track MDN assimilation in biota, although it has not been extensively tested for this purpose. Limited available data show $\delta^{34}S$ from adult Pacific salmon to range between 18 and 20%o ($N = 20$; C. A. Stricker, unpublished data) and values in freshwater systems are typically much lower (e.g., $\approx -10$; Hesslein et al. 1991). Thus, both stable isotope systems have marine endmembers that are enriched in the heavier isotope, but endmember separation tends to be much larger for $\delta^{34}S$, which is a useful characteristic for those interested in making quantitative diet estimates using mixing models as increased separation should yield higher resolution (Newcombe et al. 2007). Another potential advantage of $\delta^{34}S$ for tracking MDN is that $\delta^{15}N$ of consumer tissues reflects the nitrogen source, but it also increases with trophic level (DeNiro and Epstein 1981, Minagawa and Wada 1984), body condition, and dietary protein (Adams and Sterner 2000, Martinez del Rio et al. 2009), potentially confounding variation in diet or nutritional status with MDN assimilation. Sulfur isotopes, borne on two essential amino acids (methionine and cysteine), are a conservative diet tracer unaffected by trophic position (Hesslein et al. 1991, Barnes and Jennings 2007).

Fatty acid analysis is another method for understanding food web relationships that can be used to track MDN. Fatty acids ingested by consumers, unless directly catabolized for energy, are stored in lipid reserves with little or no modification; thus the fatty acid composition of a consumer reflects that of its food sources (Iverson et al. 2004). Production of different polyunsaturated fatty acids by freshwater (including riparian) and marine producers leads to distinct fatty

---

**Table 4. Delta $^{15}N$ values for horsetail and macroinvertebrates from the 27 sampling stations across three seasons.**

<table>
<thead>
<tr>
<th>Stream</th>
<th>Station</th>
<th>Horsetail $^{15}N$ (%)</th>
<th>Macroinvertebrate $^{15}N$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spring</td>
<td>Summer</td>
</tr>
<tr>
<td>Juneau (salmon-free)</td>
<td>lower</td>
<td>2.0</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>0.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Quartz</td>
<td>lower</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>−0.2</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>−1.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Russian</td>
<td>lower</td>
<td>2.0</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>5.9</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Happy (salmon-free)</td>
<td>lower</td>
<td>2.6</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>0.3</td>
<td>3.0</td>
</tr>
<tr>
<td>N.F. Anchor</td>
<td>lower</td>
<td>...</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>1.7</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>S.F. Anchor</td>
<td>lower</td>
<td>3.7</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>4.4</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>3.5</td>
<td>4.1</td>
</tr>
<tr>
<td>China Poot (salmon-free)</td>
<td>lower</td>
<td>...</td>
<td>−0.3</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>...</td>
<td>−0.9</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>−1.7</td>
<td>−0.9</td>
</tr>
<tr>
<td>Barabara</td>
<td>lower</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>−1.4</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>2.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Humpy</td>
<td>lower</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>0.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td>−0.5</td>
<td>...</td>
</tr>
</tbody>
</table>

Notes: $N = 5$ per station and season for horsetail. $N = 1$ composite sample per station and season for macroinvertebrates. Seldovia-area streams were not sampled during the fall and horsetail was not sampled at any of the stations during the fall; other missing data were due to unavailability at the time of sampling or logistical problems.
Table 5. Dolly Varden $\delta^{15}$N, $\delta^{34}$S, and $\delta^{13}$C values (and sample sizes) for the 27 sampling stations across three seasons.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Station</th>
<th>Dolly Varden $\delta^{15}$N (%)</th>
<th>Fall (N)</th>
<th>Dolly Varden $\delta^{34}$S (%)</th>
<th>Fall (N)</th>
<th>Dolly Varden $\delta^{13}$C (%)</th>
<th>Fall (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juneau (salmon-free)</td>
<td>lower</td>
<td>Spr. (N)</td>
<td>6.2 (3)</td>
<td>7.8 (4)</td>
<td></td>
<td>Spr. (N)</td>
<td>4.9 (3)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>6.2 (4)</td>
<td>6.5 (3)</td>
<td></td>
<td></td>
<td>6.2 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>6.7 (4)</td>
<td>7.8 (2)</td>
<td></td>
<td></td>
<td>2.2 (4)</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td></td>
<td>11.6 (5)</td>
<td>11.4 (5)</td>
<td></td>
<td></td>
<td>8.2 (3)</td>
</tr>
<tr>
<td>Quartz</td>
<td>middle</td>
<td></td>
<td>6.4 (5)</td>
<td>7.9 (5)</td>
<td></td>
<td></td>
<td>5.1 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>9.1 (5)</td>
<td>7.6 (5)</td>
<td></td>
<td></td>
<td>7.5 (3)</td>
</tr>
<tr>
<td>Russian</td>
<td>lower</td>
<td></td>
<td>12.3 (2)</td>
<td>12.7 (1)</td>
<td></td>
<td></td>
<td>8.5 (2)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>11.1 (1)</td>
<td></td>
<td></td>
<td></td>
<td>5.7 (1)</td>
</tr>
<tr>
<td>Happy (salmon-free)</td>
<td>lower</td>
<td></td>
<td>11.5 (3)</td>
<td>11.4 (4)</td>
<td></td>
<td></td>
<td>2.1 (3)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>7.8 (6)</td>
<td>8.3 (5)</td>
<td></td>
<td></td>
<td>2.0 (5)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>7.9 (3)</td>
<td>7.6 (6)</td>
<td></td>
<td></td>
<td>1.5 (3)</td>
</tr>
<tr>
<td>N.F. Anchor</td>
<td>lower</td>
<td></td>
<td>9.1 (2)</td>
<td></td>
<td></td>
<td></td>
<td>9.5 (2)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>10.1 (3)</td>
<td></td>
<td></td>
<td></td>
<td>4.2 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>8.0 (6)</td>
<td>8.9 (5)</td>
<td></td>
<td></td>
<td>1.3 (4)</td>
</tr>
<tr>
<td>S.F. Anchor</td>
<td>lower</td>
<td></td>
<td>11.1 (2)</td>
<td>9.9 (1)</td>
<td></td>
<td></td>
<td>4.7 (2)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>9.5 (3)</td>
<td>8.8 (5)</td>
<td></td>
<td></td>
<td>4.6 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>8.3 (3)</td>
<td>8.0 (3)</td>
<td></td>
<td></td>
<td>2.3 (3)</td>
</tr>
<tr>
<td>Barabara</td>
<td>lower</td>
<td></td>
<td>6.4 (3)</td>
<td>9.2 (5)</td>
<td></td>
<td></td>
<td>3.5 (3)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>4.7 (3)</td>
<td>5.1 (5)</td>
<td></td>
<td></td>
<td>7.3 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>4.9 (3)</td>
<td>5.1 (5)</td>
<td></td>
<td></td>
<td>5.4 (3)</td>
</tr>
<tr>
<td>Humpy</td>
<td>lower</td>
<td></td>
<td>9.5 (5)</td>
<td></td>
<td></td>
<td></td>
<td>3.3 (3)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td></td>
<td>11.1 (5)</td>
<td></td>
<td></td>
<td></td>
<td>7.3 (3)</td>
</tr>
<tr>
<td></td>
<td>upper</td>
<td></td>
<td>8.3 (5)</td>
<td></td>
<td></td>
<td></td>
<td>3.2 (3)</td>
</tr>
</tbody>
</table>

Notes: Spr. = spring, Sum. = summer. Seldovia-area streams were not sampled during the fall and no Dolly Varden were found in China Foot Creek; other missing data were due to unavailability at the time of sampling or logistical problems.

Optima mass spectrometer (Micromass, Manchester, UK) (Fry et al. 1992). Approximately 1–2 mg of vanadium pentoxide ($V_2O_5$) was added to each tin capsule as a combustion aid for the measurement of sulfur isotope ratios using an ECS4010 elemental analyzer (Costech Analytical Technologies, Valencia, California, USA) interfaced to a Thermo-Finnigan DeltaPlus XP mass spectrometer (Giesemann et al. 1994). Results are reported in $\delta$-notation as deviations in parts per thousand (%$\delta$) relative to a monitoring gas as follows:

$$\delta X = \left( \frac{R_{\text{sample}}}{R_{\text{standard}}} \right) - 1$$

where $X$ is the rare isotope ($^{15}$N, or $^{34}$S) and $R$ is the appropriate isotope ($^{15}$N/$^{14}$N or $^{34}$S/$^{32}$S) ratio. Nitrogen isotopic compositions were normalized to USGS 40 ($\delta^{15}$N = $-4.52\%$) and USGS 41 ($\delta^{15}$N = $47.57\%$) and reported relative to the internationally accepted scale, air. Sulfur isotopic compositions were normalized to NBS 127 (21.1%) and IAEA-SO-6 (−34.05%) and reported relative to the internationally accepted scale, V-CDT. Analytical error was ±0.2%.
Dolly Varden fatty acid composition was measured at the National Marine Fisheries Service laboratory in Juneau, Alaska. Lipid was extracted from 0.5 to 1.0 g of wet sample homogenate using a modification of Folch’s method outlined by Christie (2003). The purified lipid was spiked with C19:0 and C23:0 fatty acids which acted as an internal standard and a surrogate standard, respectively and then trans-esterified to fatty acid methyl esters (FAMEs). The FAMEs injected into a cyanopropyl-bonded fused silica column in a CP3800 gas chromatograph equipped with Saturn model 2200 mass spectrometer (Varian, Palo Alto, California, USA) operating in selective ion storage mode. Fatty acid concentrations were determined using five-point calibration curves for each FAME normalized to the internal standard recovery. Blank, duplicate and reference (NIST Standard reference material number 1946) sample spectra were used for QA evaluation.

Water samples were analyzed by Cook Inlet-keeper’s water quality lab in Homer, AK according to standard methods (APHA 2005) on a Technicon Autoanalyzer II (SEAL Analytical, Mequon, Wisconsin, USA). The phenelate method was used to determine NH₄-N (ammonium-N) concentrations and the ammonium molybdate method was used to determine PO₄-P (orthophosphate-P) concentrations.

### Quantifying spawner abundance

We quantified MDN abundance as local spawner density (LSD), expressed in MT (metric tons)/km or, equivalently, kg/m. Estimates of LSD were based on ADF&G escapement monitoring point for each of the salmon streams. ADF&G used weirs to census escapement to the Russian River (ADF&G 2006) and the North and South Forks of the Anchor River (Kerkvliet et al. 2008); repeated ground surveys to estimate escapement on Humpy and Barabara creeks (Hammarstrom and Ford 2008); and annual ground surveys to estimate escapement on Quartz Creek (ADF&G, unpublished data). We divided escapement by the length of stream used by spawning salmon, approximated from ADF&G’s anadromous waters catalog (ADF&G 2005) to give stream-specific estimates of spawner densities. To account for within-stream variation in spawner abundance, we conducted several ground surveys over a 500-m stream reach at each salmon-bearing station and, at stations where our surveys deviated substantially from the stream-specific spawner density estimates, we adjusted spawner densities accordingly. We used year-specific average mass for individuals of each species (Hammarstrom and Ford 2008, Kerkvliet et al. 2008) to convert spawner densities into biomass.

We used 2005 salmon spawner data as predictors for MDN measures in samples collected during summer and fall. Since our spring sampling was conducted prior to the onset of the 2005 spawning runs, we used 2004 spawner data as predictors for these samples. LSD in salmon streams ranged from 0.3–22 MT/km in 2004 and from 0.3–23 MT/km in 2005 (Table 6). There is undoubtedly some error associated with estimates of LSD, but given the nearly two order of magnitude range observed across the study.

### Table 6. Local spawner density during 2004 and 2005 at sampling stations on the nine study streams in three regions.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Station</th>
<th>LSD 2004 (MT/km)</th>
<th>LSD 2005 (MT/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper Landing</td>
<td>Juneau</td>
<td>lower 0</td>
<td>middle 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>upper 0</td>
<td>0</td>
</tr>
<tr>
<td>Quartz</td>
<td>lower 2</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>middle 1</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Russian</td>
<td>lower 22</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>middle 7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Homer</td>
<td>Happy lower 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>middle 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>upper 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N.F. Anchor</td>
<td>lower 0.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>middle 0.3</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>upper 0.3</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>S.F. Anchor</td>
<td>lower 2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>middle 2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Seldovia</td>
<td>lower 0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>China Poot</td>
<td>lower 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>middle 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barabara</td>
<td>lower 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>middle 0.4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>upper 0.4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Humpy</td>
<td>lower 8</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>middle 8</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>upper 8</td>
<td>23</td>
<td>23</td>
</tr>
</tbody>
</table>

Note: MT = metric tons.

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Table 7. Ranking of a priori models for dissolved nutrients and stable isotopes and fatty acids in biota.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Model</th>
<th>K</th>
<th>AICc</th>
<th>ΔAICc</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>log NH₄-N</td>
<td>intercept + LSD + region + season + (LSD × season)</td>
<td>10</td>
<td>115.59</td>
<td>0</td>
<td>0.82</td>
</tr>
<tr>
<td>log PO₄-P</td>
<td>intercept + LSD + region + season</td>
<td>8</td>
<td>119.22</td>
<td>3.64</td>
<td>0.13</td>
</tr>
<tr>
<td>Horsetail δ¹⁵N</td>
<td>intercept + LSD + region + season + (LSD × season)</td>
<td>10</td>
<td>88.75</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region</td>
<td>6</td>
<td>202.79</td>
<td>0</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + season + (LSD × season)</td>
<td>7</td>
<td>202.95</td>
<td>0.16</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>intercept + season</td>
<td>4</td>
<td>203.09</td>
<td>0.29</td>
<td>0.18</td>
</tr>
<tr>
<td>Scraper δ¹⁵N</td>
<td>intercept + LSD + region</td>
<td>6</td>
<td>208.44</td>
<td>0</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>intercept + region</td>
<td>5</td>
<td>209.75</td>
<td>1.31</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + season + (LSD × season)</td>
<td>10</td>
<td>212.08</td>
<td>3.63</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + season</td>
<td>8</td>
<td>212.91</td>
<td>4.47</td>
<td>0.06</td>
</tr>
<tr>
<td>Generalist δ¹⁵N</td>
<td>intercept + LSD + region</td>
<td>6</td>
<td>205.53</td>
<td>0</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + season</td>
<td>8</td>
<td>206.14</td>
<td>0.60</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + season + (LSD × season)</td>
<td>10</td>
<td>207.90</td>
<td>2.37</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + fork length</td>
<td>7</td>
<td>183.13</td>
<td>0</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + fork length + (LSD × fork length)</td>
<td>6</td>
<td>185.50</td>
<td>2.37</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + fork length</td>
<td>5</td>
<td>185.78</td>
<td>2.64</td>
<td>0.12</td>
</tr>
<tr>
<td>Dolly Varden δ³⁴S</td>
<td>intercept + LSD + region + fork length + (LSD × fork length)</td>
<td>8</td>
<td>275.42</td>
<td>0</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + fork length + season + (LSD × fork length)</td>
<td>10</td>
<td>279.19</td>
<td>3.77</td>
<td>0.11</td>
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<tr>
<td></td>
<td>intercept + LSD + region + fork length</td>
<td>6</td>
<td>279.59</td>
<td>4.17</td>
<td>0.09</td>
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<td></td>
<td>intercept + LSD + region + fork length + season + (LSD × fork length)</td>
<td>7</td>
<td>280.73</td>
<td>5.31</td>
<td>0.05</td>
</tr>
<tr>
<td>Dolly Varden δ⁰³:δ⁰⁶</td>
<td>intercept + LSD + fork length + (LSD × fork length)</td>
<td>6</td>
<td>232.73</td>
<td>0</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + fork length + season + (LSD × fork length)</td>
<td>8</td>
<td>234.58</td>
<td>1.85</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>intercept + LSD + region + fork length + (LSD × fork length)</td>
<td>8</td>
<td>236.72</td>
<td>3.99</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Notes: LSD = local spawner density. In addition to the parameters listed, all models contained stream as a random intercept. Models are ranked by AICc for each dependent variable and only top-performing models (i.e., those with w > 0.05) are shown.

Data analysis

We defined an a priori set of linear regression models that corresponded to hypotheses regarding the influence of environmental factors on dissolved nutrient concentrations and biotic stable isotope and fatty acid signatures. We used Akaike’s Information Criterion (adjusted for small sample size, AICc; Akaike 1973, Burnham and Anderson 2002) to rank and weight the models in the candidate set and then calculated model-averaged estimates—i.e., a weighted average of the estimates made by every model in the set—with unconditional standard errors (Burnham and Anderson 2002). We used package AICcmodavg (Mazerolle 2011) in the statistical platform R (R Development Core Team 2011) for the analyses, using each sampling event within each station as an experimental unit. Because multiple fish and horsetail samples were analyzed for each station, we averaged the data from each at a given station on a given date (Tables 4 and 5). Dissolved nutrient data (i.e., NH₄-N and PO₄-P) required log transformation to meet model assumptions.

For Dolly Varden, our model set expressed δ¹⁵N, δ³⁴S, and δ³⁰:δ⁰⁶ as a function of LSD (MT/km), region, fork length, season, and the interactions season × spawner abundance and fork length × spawner abundance. Our Dolly Varden model set was identical for all three dependent variables and consisted of the global model and all possible subsets of independent variables and interaction terms for a total of 25 candidate models. For macroinvertebrate δ¹⁵N, horsetail δ¹⁵N, and log-transformed dissolved nutrient concentrations, our model set expressed dependent variables as a function of LSD, region, season, and the interaction season × LSD. This model set consisted of the global model and all possible subsets of the independent variables and the interaction term for a total of nine candidate models. In addition, we included stream as a random intercept in each model to account for any stream effects. We confined interaction terms...
to models where both interacting effects were also present as main effects. We included season \( \times \) spawner abundance interaction terms to allow dependent variables to be constant in salmon-free streams but to vary in response to seasonal fluctuations in MDN availability in salmon-bearing streams. We included the fork length \( \times \) spawner abundance interaction term because we hypothesized that larger Dolly Varden may assimilate more MDN than smaller individuals. Since we were interested in seasonal variation in the effect of spawning salmon abundance on our dependent variables, we plotted model-averaged estimates (\( \pm 2 \) unconditional SE = 95% CI) of the LSD effect (5 levels representing the observed range of LSD) for each season, holding all other predictors constant (i.e., region = Cooper Landing, fork length = 100 mm).

RESULTS

**Dissolved nutrients**

The best approximating models for log \( \text{NH}_4 \)-N and log \( \text{PO}_4 \)-P contained LSD, region, season, and LSD \( \times \) season interaction (Table 7). Concentrations of both nutrients increased with spawner abundance during the summer spawning season, when point estimates of concentrations for both nutrients increased by approximately two orders of magnitude across the observed range in spawner density (i.e., 0–20 MT/km; Fig. 2). Concentrations of neither nutrient were conclusively related to spawner abundance during spring or fall (Fig. 2).

**Horsetail and macroinvertebrate \( \delta^{15}N \)**

The best approximating models for \( \delta^{15}N \) in horsetail, scrapers, and generalist macroinvertebrates each consisted of LSD and region (Table 7). There was some support for season and LSD \( \times \) season interactions in the lower-ranked models (Table 7), although these effects had little influence on the model estimates (Fig. 3). Across the observed range in spawner density, point estimates for \( \delta^{15}N \) in generalist macroinvertebrates increased from approximately 3% to >6% in all seasons (Fig. 3). Point estimates for horsetail and scraper \( \delta^{15}N \) at salmon-free stations were approximately 2% and 3.5%, respectively, during summer and fall. Delta \( ^{15}N \) for both taxa increased slightly with spawner density, but the high error in these estimates made it impossible to determine if the trends were real (Fig. 3). We did not sample horsetail in the fall and we did not model scraper data from fall samples because they were found at relatively few stations during the fall and at no stations with LSD >5 MT/km.

**Dolly Varden stable isotopes and fatty acids**

For all three Dolly Varden MDN metrics, the effects of LSD and fork length were strongly supported by the data, and the effect of region was important for both stable isotope metrics (Table 7). An LSD \( \times \) fork length interaction was
strongly supported for $\delta^{34}S$ and $\omega3:o6$, and supported less so for $\delta^{15}N$ (Table 7). For $\delta^{34}S$ and $\omega3:o6$ there was also a small level of support for a season effect and no support for a LSD $\times$ season interaction (Table 7). The season effect had no discernible influence on the model estimates, which were essentially identical for each metric across the three seasons (Fig. 4). Across the range of observed spawner density, point estimates increased from approximately 8.2\% to 12.3\% for $\delta^{15}N$, from 1.3\% to 12\% for $\delta^{34}S$, and from 4 to 8.8 for $\omega3:o6$ during spring, summer, and fall (Fig. 4).

**DISCUSSION**

Ammonium-N and orthophosphate-P concentrations increased with spawner density during the summer but not during spring or fall, indicating the presence of a dissolved nutrient spike that had largely attenuated by fall sampling. Previous studies tracking dissolved nutrients have shown similar patterns (Minakawa and Gara 1999, Chaloner et al. 2002, Johnston et al. 2004, Mitchell and Lamberti 2005, Claeson et al. 2006). Delta $^{15}N$ in horsetail and scraper macroinvertebrates did not vary with spawner density in any season, suggesting little or no MDN assimilation by these lower trophic levels. Horsetail is capable of fixing atmospheric nitrogen (Uchino et al. 1984), while nitrate reductase activity also suggests it competes for soil nitrate (Nadelhoffer et al. 1996), making it difficult to determine the extent to which assimilated nitrogen came from the soil. Previous work showed a lack of MDN assimilation by green alder (*Alnus crispa*), also a nitrogen fixer, in contrast to three other plant species that were isotopically enriched along salmon spawning reaches (Helfield and Naiman 2002). The apparent lack of MDN assimilation by scraper macroinvertebrates contrasts previous work that showed seasonally persistent nitrogen enrichment in primary consumers (i.e., grazers) from a salmon stream relative to a non-salmon stream (Bilby et al. 1996), although the basis for this contrast is not clear.

Spawner density was an important predictor for all MDN metrics in biota and the top model for each response included this predictor. Predictions based on these models showed that

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**Fig. 3.** Model-averaged estimates for $\delta^{15}N$ in horsetail and macroinvertebrates (and 95\% CI) during spring (triangles), summer (squares), and fall (circles) across five levels of local spawner density, holding region constant. MT = metric tons.
generalist macroinvertebrates and Dolly Varden incorporated more MDN as spawner density increased. The evidence was particularly strong for Dolly Varden, where three independent biochemical metrics indicated assimilation of marine nitrogen, sulfur, and fatty acids. At the highest salmon abundance, point estimates for $\delta^{15}$N in Dolly Varden (after subtracting $3\%$ for trophic fractionation; Minagawa and Wada 1984) approached that of Pacific salmon (i.e., $10–15\%$; Johnson and Schindler 2009). The highest point estimates for $\delta^{34}$S, by contrast, were depleted by approximately $6\%$ relative to Pacific salmon (i.e., $18–20\%$; C. A. Stricker, unpublished data). Dolly Varden $\alpha\beta:\gamma$ exceeded the maximum observed in salmon flesh (i.e., $7.3$; R. A. Heintz, unpublished data), suggesting that salmon eggs (with $\alpha\beta:\gamma$ of $12.1–13.9$; R. A. Heintz, unpublished data) were an important dietary component (Denton et al. 2009, 2010, Jaecks 2010). Maximum $\delta^{15}$N in generalist macroinvertebrates was substantially less than that of salmon, implying incorporation of less MDN. Our findings support the prevailing view in the literature that generalist consumers, represented in this case by Dolly Varden and macroinvertebrates, are the most likely to capitalize on and benefit from pulsed subsidies (Ostfeld and Keesing 2000, Sears et al. 2004, Yang et al. 2008).

The effect of spawner density on MDN assimilation by generalist macroinvertebrates and Dolly Varden was similar during each season measured, indicating that MDN in these taxa persisted for at least nine months following salmon spawning. Direct consumption of MDN in the form of salmon eggs and flesh has been observed for Dolly Varden (Denton et al. 2009, 2010, Jaecks 2010) and all of the generalist macroinvertebrate taxa we sampled (Piorkowski 1995, Minakawa and Gara 1999, Minakawa et al. 2002, Claeson et al. 2006, Walter et al. 2006). We hypothesize that MDN persistence in consumer tissues may be driven by one or two non-mutually exclusive mechanisms. One possible mechanism relates to low winter energetic demands and slow tissue turnover in poikilotherms in a setting where water temperatures barely exceed $0^\circ$C during the winter months. For example, tissue turnover of whitefish ($Coregonus$ spp.) muscle during fall and winter was negligible, allowing the $C$, $N$, and $S$ stable isotope

Fig. 4. Model-averaged estimates for Dolly Varden stable isotopes and fatty acids (and 95% CI) during spring (triangles), summer (squares), and fall (circles) across five levels of local spawner density, holding region and fork length constant. MT = metric tons.
composition of summer growth to be reflected year-round (Hesslein et al. 1993, Perga and Gerdeaux 2005). Another potential mechanism is that MDN stored in the stream environment was consumed through the winter and spring. Possible direct sources of stored MDN include incubating or dead salmon eggs, salmon flesh entrained in snags or sediment, and emerging salmon fry, while possible indirect pathways include leaves, invertebrates, and microbes that have been subsidized by MDN.

An independent data set for Dolly Varden and juvenile coho salmon collected in Kenai Peninsula salmon streams showed MDN presence and associated nutritional benefits to persist through winter and into the following spring (Rinella et al. 2012). This study, together with the current study, contrasts others examining MDN persistence in aquatic consumers, which have generally shown MDN levels to decrease in the months following salmon spawning (Bilby et al. 1996, Claeson et al. 2006, Walter et al. 2006, Reichert et al. 2008, Honea and Gara 2009). However, these studies were conducted in Washington, USA streams with lower spawner densities and relatively warm winter water temperatures that would allow higher metabolic rates and tissue turnover.

Our results also show that, while spawner abundance is an important predictor, other factors contribute to variation in MDN metrics. Region was an important predictor for every MDN metric except Dolly Varden $\omega 3:0\omega 6$, suggesting that regions have unique backgrounds upon which spawning salmon effects are superimposed. Nitrogen isotopes most clearly demonstrate this phenomenon. Scraper macroinvertebrates hold the lowest trophic position and should, therefore, most closely reflect the dissolved nitrogen pool (Cabana and Rasmussen 1996). Scraper $^{15}\text{N}$ from salmon-free stations was $6.9 \pm 1.5\%$ (mean $\pm$ standard deviation) in the Homer region, $2.7 \pm 1.5\%$ in Cooper Landing, and $-0.2 \pm 0.4\%$ in Seldovia. Understanding the basis for these regional differences is outside the scope of this study, but a few potentially additive causes stemming from differences in watershed nitrogen sources (Peterson and Fry 1987, Cabana and Rasmussen 1996) or subsequent isotopic fractionation of the nitrogen pool can be postulated. One influence may be differences in the extent of alder cover which, through nitrogen fixation, can contribute significant quantities of atmospherically-derived nitrogen (i.e., $0\%$ by definition) to aquatic and riparian ecosystems (Helfield and Naiman 2002, Shaftel et al. 2012). Another factor could be differences in denitrifying potential of riparian soils, where fine-textured soils along meandering stream reaches can support high denitrification rates and, in turn, isotopic enrichment of the dissolved nitrate pool (Pinay et al. 2003). Lastly, water chemistry samples from salmon-free stations indicated that primary production may have been limited by nitrogen availability in the Homer streams (total molar N:P = 17) but not in the other regions (total molar N:P > 100), possibly leading to discriminatory assimilation of the light isotope by primary producers in the Cooper Landing and Seldovia regions (Teranes and Bernasconi 2000, Brahney et al. 2006). Similar differences in source and fractionation may explain regional differences in baseline sulfur isotopes.

Fork length was an important predictor for all three Dolly Varden MDN metrics, and model parameters indicated that MDN assimilation increased with fork length. Interactive effects were also supported, especially for $\delta^{34}\text{S}$ and $\omega 3:0\omega 6$, indicating size-mediated differences where larger fish appeared to assimilate more MDN. This differential MDN assimilation may be due to intraspecific competition where larger individuals are better able to compete for drifting eggs and flesh. Additionally, larger individuals are released from gape limitation that may prevent smaller individuals from consuming salmon eggs (Armstrong et al. 2010). Without diet and behavioral data these explanations are speculative and further studies are required to determine the mechanism for the observed size-dependent responses.

This study demonstrated that seasonally pulsed MDN resources can persist for many months in some biota and, together with other studies (Verspoor et al. 2010, Rinella et al. 2012), suggests that salmon can have prolonged effects in ecosystems where they spawn. While MDN persisted in most taxa sampled over the three-season course of this study, we were unable to determine the full duration of its presence. This is a worthwhile research objective, since interannual persistence would help to buffer changes in...
MDN availability during years of low salmon returns.

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Summary

The Alaska Department of Natural Resources (DNR) has rejected the Chuitna Citizens Coalition and Cook Inletkeeper Jan. 21, 2010 petition to declare streams and their riparian corridors in the Chuitna River watershed as unsuitable for mining by claiming that best available reclamation technology would allow the establishment of pre-mining water balances. Even if an average annual recharge rate could be reestablished, it is the combination of site lithology and material properties that control the rate that baseflow discharges to the streams. The best available technology is concurrent excavation and backfill, which in the Chuitna watershed would excavate two aquifers that have different properties and thoroughly mix the material prior to backfilling it as mining proceeds. The current unique combination of groundwater storage, artesian pressure, horizontal and vertical conductivity, compaction and recharge cause the baseflow hydrograph that sustains streamflows during the low-flow periods of the year. The best available technology would dig up and remove the current layering and completely change the properties that control the flow through the backfill. Consequently, based on best available reclamation technology, it is not technologically feasible to restore water balances to pre-mining conditions.

Introduction

DNR rejected the petition to declare streams in the Chuitna River watershed as unsuitable for mining; the petition had been prepared by Trustees for Alaska on behalf of Cook Inletkeepers and Chuitna Citizens Coalition. This technical memorandum reviews the DNR’s findings that consider hydrology in support of DNR’s decision.
With respect to hydrology, reclamation must be able to restore the hydrologic balance so that recharge and discharge mimic the pre-mine rates. Myers (2011) presented a detailed conceptual model of the Chuitna watershed that outlines the factors which must be included in a successful reclamation. The DNR decision did not consider Myers (2011), and that report is again attached as an appendix to this technical memorandum and references herein are made to that report. See Appendix 1.

Review of DNR Response Paragraphs

A site must be considered unsuitable for mining if reclamation cannot reasonably restore pre-mine groundwater conditions, including the hydrologic balance driven by recharge. DNR claims that reclamation is feasible and that it would reestablish groundwater in a “condition similar but not identical to the pre-mining condition.”

124. Petitioners' argument also overlooks the fact that state and federal agencies have made findings that reclamation in this area is technologically feasible. In the 1990 FEIS on the Diamond Shamrock Chuitna Coal Project, EPA stated that “[r]eclamation of the mine area would at least partly reverse the ground-water impacts from mining. After removal of the surface-water diversion systems, surface water together with incident precipitation would recharge the underlying spoil materials and with time result in the reestablishment of a ground-water regime similar but not identical to the premining condition.” (DNR Para. 124)

DNR’s claim is that a “ground-water regime similar but not identical to the pre-mining condition” could be established in the watershed after mining and that with proper planning “the impacts can be minimized.” A mine must be able to restore recharge capacity that (11AAC 90.343): “(1) supports the approved postmining land use, (2) minimizes and disturbance of the prevailing hydrologic balance in the mining area, and (3) provides a recharge rate approximating the premining recharge rate.” Although recharge rate is just one aspect of the “prevailing hydrologic balance,” DNR’s performance standards rely on reestablishing the recharge rate.

Even if the historic steady state recharge rate could be reestablished, DNR ignores the lag time that the natural stratigraphy and lithology cause to the flow regime, factors which result in the unique timing of baseflow discharge to the streams. It is essentially impossible to restore the natural lithology as pits are backfilled and compacted (Paul et el 2007). Recharge must not

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discharge to the streams too quickly or the winter baseflow will be decreased to less than occurs at present. Postmining discharges to the streams must reestablish the premining exchange of water between the streams and the groundwater, through the hyporheic zone (Hancock 2002), although surface/groundwater interactions are the most complex in hydrogeology (Sophocleous 2002). Myers (2011) describes the lithology and variability in groundwater levels that control the discharge of groundwater to the streams. DNR does not even address the timing of discharge or stratigraphy/lithology of the aquifers.

DNR’s FEIS quote is selective; the following paragraph from the 1990 FEIS contains a more-complete discussion.

Reclamation of the mine area would at least partly reverse the ground-water impacts from mining. After removal of the surface-water diversion systems, surface water together with incident precipitation would recharge the underlying spoil materials and with time result in the reestablishment of a ground-water regime similar but not identical to the premining condition. It is anticipated that the water quality might be somewhat poorer than the premining quality due to the nature of the spoil material, e., intermixed clay, sand, and gravel. That is, the ground water would likely shift from calcium bicarbonate type to calcium and sodium sulfate type associated with an increase in total dissolved solids. However, the premining condition of progressively lower water quality with depth could persist in the reclaimed spoil aquifer. Postmining aquifer properties would also vary from premining conditions; however, this impact would not be expected to adversely affect the regeneration of the postmining hydrogeologic regime since the subsurface materials would probably be permeable and have some capacity for storage and transmission of ground water. The reestablishment of the ground-water regime and, in turn, reestablishment of the surface streams would likely require decades. This is governed by the necessary condition of establishing a equilibrium between the ground-water and surface-water regimes. If an equilibrium condition similar to the existing condition cannot be established, then maintenance of the baseflow contribution to streams during low flow periods might not be achievable. The elevation of the shallow aquifer water table relative to postreclamation ground surface elevations cannot be predicted with sufficient accuracy to assure base flow contribution to restored stream channels. (1990 FEIS at 5-20, bold in original, italics added).

The FEIS does suggest that a recharge regime could be reestablished, but it also acknowledges that the groundwater elevations might not be achieved with sufficient accuracy to adequately maintain baseflow to the streams, critical for winter habitat. Baseflow is the most important aspect of reclaiming streamflows and, along with stream form, is the most important aspect of fish habitat. Failure to reestablish pre-mine baseflow is a failure to reestablish fish habitat.

In its decision, DNR additionally relied on statements in the 1990 FEIS to support its decision:
155. As stated earlier, one of ASCMCA's purposes is to minimize adverse impacts to the hydrologic balance, including the recharge capacity within the mine area, and this is reflected in 11 AAC 90.343. As expressed in the 1990 FEIS, the EPA concluded that the proposed reclamation was essential to minimizing adverse impacts and would facilitate recharge of the "groundwater regime similar but not identical to the premining condition." This finding is again supported by DNR's 1987 Permitting Decision to issue the permit for the Diamond Shamrock Chuitna Coal Mine. As required by AS 27.21.180(c)(3), the permitting decision found that there would be no material damage to the project or surrounding areas. (DNR Para. 155, italics in original.)

This paragraph continues DNR’s selective quoting from the 1990 FEIS, while not addressing the need to reestablish pre-mining lithology so that discharge will be timed as occurs currently (Hancock 2002). DNR Para. 125 cites to the 1990 FEIS to state that “with proper planning, the impacts can be minimized” without citing one example of a mine reclamation that has completely rebuilt aquifers so that the amount and time of pre-mining recharge and discharge has been replicated to any extent.

125. Nonetheless, the petitioners selectively cite portions of the 1990 FEIS to assert that reclamation of wetlands and riparian areas is not technologically feasible. The petitioners cite statements that, at first blush, appear to support their allegations, but omit other statements that discuss potential impacts and proposed reclamation that ultimately negate the contention that reclamation of coal mining activities is not technologically feasible. For example, petitioners quote the following from the 1990 FEIS regarding impacts to groundwater: "Impacts to groundwater regime as a result of mining operations would be substantial and would affect recharge and discharge relationships; quantity, quality, and direction of groundwater flows; and quantity and quality of surface water." However, petitioners fail to mention two other key observations EPA reached: "These impacts are unavoidable; however, with proper planning, the impacts can be minimized." (DNR Para. 125, emphasis added.)

DNR claimed the petition selectively quoted from the 1990 FEIS regarding the infeasibility of reclaiming wetlands and riparian areas, but the FEIS acknowledges these major impacts are unavoidable. They are unavoidable because the most difficult aspect to reclaim is the hydrograph of stream baseflow, as pointed out by Myers (2011).

DNR paragraph 137 alludes to modern analytical tools which could be used to design the reclamation. Regarding groundwater hydrology, it refers to the groundwater model MODFLOW: “Modern groundwater models, such as MODFLOW developed by the USGS, are able to predict mining impacts to groundwater and instream flows, allowing a mine operator to formulate plans to mitigate potential water table declines and associated stream flow losses during mining, as well as proving a means to mitigate impacts after mining while groundwater
elevations naturally recover.” (DNR Para. 137). MODFLOW is a physically based groundwater flow model with parameters describing hydrogeologic processes. MODFLOW and other numerical models can simulate groundwater flow accurately if the structure and properties of the aquifer are known and there are observation data to which to calibrate the model, although the accuracy decreases with size of the model domain, as pointed out by the National Marine Fisheries Service (2007). The ability to simulate does not establish the ability to construct or recreate existing groundwater conditions, which requires much data and much uncertainty remains (Binley et al, 1991). MODFLOW can precisely simulate flow through aquifer sections that a mining company cannot construct. DNR paragraph 146 criticizes petitioners’ technical reports as not including sufficient data, being speculative, or being based on an assumption that no impacts at all are allowed.

It is also important to note that contemporary mining practices have also changed with the advance of new technology and increased understanding of reclamation processes. Contemporary mining practices require continuous monitoring and mitigation of reclaimed areas. The petitioners and the authors of the commissioned reports base their arguments on the erroneous assumption that no adverse impacts at all are allowed to fish and wildlife habitat, wetlands, and site hydrology as a result of surface coal mining operations. (DNR Para. 146)

The proposed mining technique in the 1990 FEIS is concurrent strip mining and backfill, the current best available technology which DNR alleges the petitioners did not consider (DNR Para. 160). The reclamation plan in the 1990 FEIS describes the backfilling operation, which would not reestablish pre-mine lithology as part of the reclamation. “After the initial box cuts have opened the pits for mining operations, the overburden and interburden material from the active mine areas will be backfilled by draglines and truck and shovel operations into the mined out areas” (1990 FEIS at 2-32). Concurrent backfill is the best available technology in 2011, just as it was in 1990. It will involve the removal of several hundred feet of overburden and interburden in addition to the coal seams. Such mining would completely remove the two primary aquifers at the site (Myers, 2011). Reviews of this type of backfill operation have found that hydrogeologic properties vary substantially from the pre-mine properties, mostly with the conductivity being much higher, porosity much lower, and with substantial preferential flow zones (Paul et al, 2007). Groundwater –surface water interactions depend on the joint effects of topography, geology, and climate (Sophocleous 2002); geology is the aspect of the premine condition that reclamation does not reestablish. The effects of dewatering an open pit site, especially in unconsolidated material, do not end at the pit or project boundary – lowering the water table substantially changes the flow paths in aquifers adjoin the site (Bonta et al, 1992). Even once backfilled, because of the changed hydrogeologic characteristics, flow paths in the backfilled mine will differ from that in the premine conditions so that flow paths in the adjoining aquifers can also be changed (Bonta et al, 1992). The long-term effects of open pit
mining extend far beyond the boundaries of the pit. It is not possible for backfilling a dewatered open pit to develop hydrogeologic characteristic similar to that which existed premine.

Although the final topography may resemble pre-mine contours, the crushing and mixing inherent with the operations just described assures that the backfill will be a relatively homogenous mixture of all lithologies, other than the coal, pre-existing on the site. There is no contemporary mining practice that minimizes the impacts of completely removing aquifers. DNR has provided no examples where degradation as complete as proposed for this site has ever been reconstructed. Monitoring would simply document the degradation.

The FEIS acknowledges that aquifer properties would vary from the pre-mining condition, but also states without reference that this would not “adversely affect” the “postmining hydrogeologic regime” because the subsurface materials would be permeable. This is no standard at all; any pile of waste would be permeable and allow recharge to flow through. To establish pre-mine hydrogeologic flow conditions, the layering and similar properties for many lithologic layers would also have to be reestablished. In order to reconstruct the pre-mine lithologies, it would be necessary to excavate overburden and interburden by layer, and to stockpile each separately. The overburden and interburden layers would be excavated separately to remove up to four seams of coal, but would be placed into one or two temporary stockpiles (Chuitna Coal Mine, Part D1) Operation Plan, at 6). Complete breakdown and mixing of the layers would occur from shoveling the interburden into trucks with payloads ranging from 150 to 400 tons using shovels that can move from 25 to 80 cubic yards per load (Id.).

For backfill, it would be necessary to handle the material a second time, backfilling it to pre-mine thicknesses and properties. The mine plan indicates that interburden, which is fine-grained materials of the Tyonek formation, will be backfilled into the bottom and the overburden placed on top of the interburden (Chuitna Coal Mine, Part D9: Backfilling and Grading Plan, at 3). The layering associated with the coal will be gone. Because the interburden is not highly consolidated, the coal seams control the vertical flow. Without them, it would be impossible to establish similar control.

Myers (2011) discussed this in detail. Even if an average recharge rate is reestablished, the most important aspect from a baseflow perspective is the rate at which the recharge flows through the backfill (Myers, 2011). The FEIS also acknowledges that it could require decades and that equilibrium “similar to the existing condition” is necessary for “maintenance of the baseflow contribution to streams during low flow periods.” Without the layering inherent in the Tyonek formation, this is impossible (Myers, 2011).

DNR improperly rejects the concept of a reasonable time to reestablish recharge capacity because DNR claims the regulations do not require this. “The petitioners assert that because "groundwater recharge capacity cannot be achieved within a reasonable timeframe, the performance standard at 11 AAC 90.343 could not be met. Specification of a reasonable time
frame is not set forth in the regulations” (DNR Para. 156). The regulations may not specify a reasonable time frame, but baseflow to the streams, an annual water budget, could be established reasonably quickly. Without the natural seasonal variability it would not be similar to pre-mine conditions. The natural seasonal variability in the groundwater levels in the watershed indicates the aquifers are rather small, with storage capacity on the order of the annual flux through them (Myers, 2011). Timing of baseflow depends on the lithology, as noted above and in Myers (2011); the lithology will result from the placement of the mine spoil, which as described will be a heterogeneous mixture of overburden and interburden. DNR has presented no references to sites or to studies which suggest that reestablishment of the natural baseflow variability could be possible.

DNR relies on the mining company meeting performance standards in 11 AAC 90.321 to protect “water quality and hydrology” (DNR Para. 161). Except for a and b, these standards apply during mine operations rather than to reclamation. The inability to restore the long-term hydrologic balance (11 AAC 90.321 (a)) has been discussed above. The next standard (11 AAC 90.321 (b)) requires that changes in groundwater depth and flow pathways be minimized; as discussed above and by Myers (2011), this performance standard would require restoration of the current lithology. Maintaining discharges to federal water quality standards (11 AAC 90.323) would not help in the reclamation of the site, and could require a permanent presence to treat discharge in perpetuity.

The 1990 FEIS states that there is no way to predict whether the new channels would have sufficient baseflow, DNR’s claims to the contrary notwithstanding. Referring to stream 2003:

> It is the applicant's intent to restore permanent stable channels along the approximate original courses of these streams after reclamation using established engineering techniques. However, the backfill material on which the restoration channels would be formed cannot be compacted to the same degree as the original bed material of these streams and would be susceptible to some erosion and degradation until geomorphologic equilibrium were attained. Remedial stabilization measures would probably be required during the early years of restoration. Furthermore, there would be no guarantee that the post-reclamation water table would coincide with the elevations of the recreated stream channels. Therefore, while it would be possible to reconstruct stream channels having physical characteristics similar to the existing stream channels, there is no way to predict whether the new channels would have sufficient base flow through the upper reaches to provide year-round flow similar to that which now exists. (1990 FEIS at 5-29)

The 1990 FEIS indicates that stream shape would be approximated, but also that it is not possible to compact “the backfill to the same degree as the original bed material” or to guarantee pre-mine water tables or “sufficient base flow.” Rather than supporting DNR’s conclusion that the site is suitable for mining, the 1990 FEIS supports the opposite conclusion: the site is unsuitable.
as regards the performance standard requiring that the natural hydrologic balance be reestablished.

DNR concluded there was insufficient data in the record to decide the site was unsuitable for mining.

172. In accordance with AS 27.21.260(c)(1), the evidence in the record is insufficient to require my determination that-- for water quality, quantity, and hydrology that may provide fish and wildlife habitat within the petition area-reclamation in accordance with ASCMCRA is not technologically feasible. Moreover, the evidence is insufficient to support the petitioners' allegation that surface coal mining operations would irrevocably alter the hydrology and aquatic productivity of the petition area, or the Chuitna watershed. (DNR Para. 172)

DNR also claimed that “there is insufficient evidence to support the claim that reclamation throughout the delineated petition area is not technologically feasible” (DNR Para. 186). In fact, the 1990 FEIS basically states that it is not possible to reclaim streams to their pre-mine conditions regarding baseflow. Concurrent backfill is the best available technology, but the 1990 FEIS indicated that it is not possible for the backfill to mimic pre-mine conditions. As also described above and in Myers (2011), a mining company must reestablish, in addition to long-term steady recharge rates, flow pathways in the backfill aquifers that will store and pass groundwater in a manner similar to that which preexisted the mine. This has never been done, and there is no evidence in the 1990 FEIS that authors of that FEIS believed it was possible to do so, and DNR has presented no examples of how it can be done nor where it has been done. The best available technology today does not provide the means to do this in the Chuitna Watershed where strip mining will occur at depths of hundreds of feet.

Reference


APPENDIX 1

MYERS 2011 CONCEPTUAL FLOW MODEL REPORT
Baseflow Conditions in the Chuitna River and Watersheds 2002, 2003, and 2004

And

The Suitability of the Area for Surface Coal Mining

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January 14, 2011
Conclusion

The Chuitna River watershed is a remarkably diverse watershed with very complicated flow patterns that affect baseflow in the three study area streams – 2002 (Lone Creek), 2003, and 2004 – and all other streams in the watershed. Baseflow in these streams is a significant component of baseflow in the overall Chuitna River into which they discharge. Surface coal mining would affect each of these streams differently and restoration faces many obstacles because the hydrologic complexity must be restored. Complexity refers to the multitude of flow paths, sources, and discharges that combined cause the baseflow hydrograph in a stream. Because the inherent variability in the distribution of wetland types, soils, unsaturated zone properties, glacial till properties, and a vertically impermeable but horizontally conductive zone as found in the mineable coal sequence cannot be restored to its pre-development function and complexity, the Chuitna River watershed is not suitable for surface coal mining.

Baseflow to the streams depends on recharge that varies around the watershed and heterogeneous properties of the wetlands, soils, and glacial drift. It also depends on a relatively impermeable layer preventing the recharge from draining too deeply. Finally, it also requires a layer beneath the glacial drift with sufficient transmissivity and connectivity with upstream sources to pass groundwater from offsite to stream 2002. Specific requirements for the restoration of baseflow include:

- The distribution of wetlands across the watershed must be replicated – not necessarily in the exact location but in the same proportion and distance from discharge points with similar underlying soils.
- The pre-development topography must be replicated along with the wetlands.
- The distribution of properties in the glacial drift is critical to reproduce because they control the flow paths from recharge to discharge. The properties are conductivity and storativity. This means the general proportions of silt and clay found heterogeneously around the watershed must be replicated.
- The hydrologic properties of the underlying coal sequence must be replicated to prevent the recharge from draining too quickly and to allow flow from west of the site to pass through to Lone Creek. This means that a layer with very low vertical conductivity but with relatively high horizontal conductivity must be restored to the site. It must also connect to the offsite source of groundwater flow.

The important result of reclamation is the replication of the flow hydrograph, and not just an average baseflow rate. If the initial rate is too high, the groundwater storage may drain too quickly so that the rate at the end of the period could be too low to support the aquatic habitat. If the aquifer stores too little water, baseflow throughout the period will be too low. Alternatively, too much recharge or too much groundwater storage would cause the baseflow to be too high which may disrupt the sediment and temperature conditions in the stream. It is essential to replicate both the average and range in baseflow to restore aquatic habitat. Failing to replicate this hydrograph is a failure to restore the site. It is impossible to restore the complexity to the watershed as documented herein, and therefore impossible to prove that the pre-development aquatic habitat can be restored.
**Introduction**

The purpose of this work is to consider whether open pit or coal strip mines constructed in the Tyonek formation in the watershed of the Chuitna River can be restored to pre-mine conditions. Specifically, this report considers whether three aspects of the system can be restored – the water balance, the recharge rates, and the aquatic habitat as affected by stream baseflow. The study area is the Chuitna River watershed with a focus on the area between stream 2002 and stream 2004, northeast of the river. Figure 1 shows the general location and features of the study area, and Figure 2 shows existing coal leases in the area.

The key components of the water balance affecting the aquatic habitat are recharge and discharge – not just their average rates and general locations, but also the variability around the study site. The critical flows which must be restored are winter baseflow. Baseflow discharge to the river controls the ability of the river to sustain the fisheries through the winter baseflow period (Trasky, 2009), from December through March (Riverside 2009, 2010). The essential baseflow characteristic is of course the flow rate, but this varies through the winter in critical ways. The baseflow must continue to follow a hydrograph similar to that before development. If baseflow is too high the baseflow channel shape may change due to changing sediment transport; if baseflow is too low there may be reduced habitat. Both increased and decreased baseflow is undesirable, so the hydrograph must be restored to its pre-mining characteristics. To maintain the predevelopment baseflow hydrograph, it is essential that the following be accurately reproduced

- Recharge volume
- Recharge timing
- Groundwater storage capabilities in the unsaturated zone
- Groundwater storage capabilities below the water table
- Flow pathways
- Hydraulic conductivity

Beyond the actual recharge rate, the aquifer system controls the baseflow to the river. Restoration must be able to restore those aquifers to pre-development conditions. This report analyzes the stratigraphy and lithology of the area and uses existing groundwater and surface water data to assess the variability of recharge and discharge. The report presents a detailed conceptual model of flow from recharge to discharge and explains its several pathways. It also describes how mining would likely change those flows and discusses the details which would need restoration to return the area to pre-mining hydrologic conditions.
Figure 1: General location map of study area. Snapped from Figure 58, Flores et al (2004).

Figure 2: General topography of lower Chuitna River watershed. The red area is Barrick-owned leases, the yellow area is PacRim coal leases, and the dashed line outlines the proposed Diamond Chuitna Coal Mine.
General Geology, Stratigraphy and Lithology of Chuitna River Watershed Aquifer System

The general geology and surface feature map (Figure 3) shows two striking structural features, the Lake Clark (also known as Castle Mountain) and Bruin Bay Faults almost compartmentalize the underlying geologic formations. The formations change at the faults indicating the faults caused significant offsets, with the area between being downdropped. Erosion exposed different formations to outcrop. Northwest of the Lake Clark fault, the surface outcrops are Tertiary aged, including a substantial volcanic plateau (Tv). The Chuitna River eroded into the Tyonek Formation (Tkt) in the area between the faults and the Beluga formation east of the Bruin Bay fault. Surficial deposits, Qs, mantle the Tyonek and Beluga formations; these are the glacial drift deposits.

The fault-caused compartmentalization creates an area of similar geology which should have similar hydrologic characteristics. The Tyonek formation contains the mineable coal and glacial outwash from several glaciations has formed the glacial drift which mantles the Tyonek formation. The land generally drains in all directions to headwater streams that combine and flow southwest toward the Chuitna River. The leased areas (Figure 2) generally correspond to the area between the faults (Figure 3), which of course reflects the Tyonek formation being sufficiently near the surface that the coal seams could be accessed. Most of the data used in this analysis was collected for the Chuitna Coal Project, but it should represent the overall study area. This memorandum accepts the data in those documents, although Hecht and Bartholomaus (2009) found them lacking in many areas.

There are two general groundwater flow systems within the study area, as defined for groundwater modeling (Arcadis, 2007), the upper and lower flow systems, respectively. They divide into four general aquifer layers at the site – from top to bottom these are alluvium and glacial drift in the upper flow system, and mineable coal sequence and sub red 1 sand in the lower flow system. Glacial drift is the term given to the glacially derived material, although some is till and some is outwash (Mine Engineers, 2008, p. 8). Below the glacial drift is the mineable coal and sub red 1 sand. The variable sourcing of the material contributes to its variable lithology, which in turn contributes to additional complexity in its hydrologic properties. The geologic and topographic complexity of a watershed combine to make the groundwater/surface water interactions more complex (Winter, 1998).

Stratigraphy and lithology are described as two distinct models to separate the flow into geologic formations, the stratigraphic layers, and between the individual layers within each geologic formation. The stratigraphic breakdown follows the convention established by the groundwater studies prepared for the project area (Riverside, 2010; Arcadis, 2007). The lithologic model recognizes that the stratigraphic formations have distinct layers with very distinct properties (such as the difference between coal seams and the sandy clay interburden).
The complex lithology of the glacial drift (or overburden) was demonstrated in the geologic sampling around the study area (Mine Engineers, 2008, Table 2). The “glacial drift to first coal seam” zone has coarse fragments over 16 observations ranging from 4.77 to 44.74%. Over 17 observations, the silt and clay percents vary from 12.6 to 52.1 and from 3.6 to 18.9% with averages of 30.1 and 10.7%, respectively. Other observations were equally variable. These variable soils control the flow through the glacial drift.

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2 It should be noted that Mine Engineers (2008) refer interchangeably to overburden and glacial drift, sometimes implying they are different formations although that is not what they mean.
The lower flow system coincides with the Tyonek formation, which consists of sedimentary rock such as sandstone and mudstone interbedded by coal seams (Flores et al, 2004 and 1994). The glacial drift lies unconformably on top of the Tyonek formation, indicating that some formations have been eroded prior to the deposition of the glacial drift. “The Tyonek Formation is a sequence of fluvial and deltaic silts, clays, and sands with occasional gravel beds and coal seams. It exhibits marked lateral and vertical facies changes, as well as extreme thickness changes, sometimes within very short distances” (PacRim, 2006, p. 7). This quote illustrates the complexity of this formation. The variable conductivity in the formation is apparent as well. “Fine-grained facies are dominant in some areas, while coarser grained sediments are dominant elsewhere. The entire unit appears to thicken westward and southward. Cemented zones are very rare, but most of the sediments have undergone substantial compaction. The sediments are more consolidated than would be expected from their present depth of burial.” (Id).

The Tyonek formation in the study area has downdropped between two faults, causing the coal outside the faults to have been mostly eroded away. Although not constrained on all sides, the supposition that the faults impede flow (Arcadis, 2007) is reasonable. Because of the faults, the streams fed by aquifers within the project area depend more on local recharge than might otherwise be the case because the faults limit the flow, although flow does enter the area from the west through lower flow system.

There are at least 18 coal seams within the study area, but just four are substantial enough for mining – the Red 1, Red 2, Red 3, and Blue seams. The formation formed in a meandering river sedimentary system where overbank wetlands once buried become coal seams (PacRim, 2006; Flores et al, 1995); because they formed on terraces, floodplains, and isolated braids, they were frequently fragmented so there is little connectivity between many of the coals seams. Because coal seam hydrologic properties vary substantially both among themselves and from the surrounding interburden (Myers, 2009), the layering likely results in substantial differences in flow rate at different points in the formation. Figure 1 shows the general lithology of the Tyonek, or mineable coal, formation, but the figure fails to highlight the horizontal variability apparent in the formations description quoted above.

The alluvium occurs only along the stream courses, so the glacial drift is effectively the upper layer to the overall system and the upper flow system.
**Conceptual Flow Model of Aquifer Systems**

A conceptual flow model is a description of the flow from source to discharge. Flow through the Chuitna River watershed system is conceptualized by considering the geology and topography, as discussed above, the groundwater levels in monitoring wells around the site in relation to the water levels in the streams, baseflow around the area, and aquifer transmissivity.

**Groundwater Level**

Riverside (2010 and 2007) and appendices provided the groundwater level data used to consider the conceptual flow in the study area. Monitoring occurred from 1983 through 1993 and again in 2006. Figure 5 shows the monitoring wells, by stratigraphy of their open interval, and the surface water monitoring points around the study area, as provided by Riverside (2009).
Long-term trends were generally not apparent in the data, so the hydrographs are not presented. The mean indicates the long-term average water level and standard deviation indicates the variability around that mean (Table 1).

The water table in the mineable coal and sub red 1 sand zones slopes from west to east, based on individual well observations (Figure 6). Riverside (2010, p. 4-23) suggests there is a transition from confined to unconfined conditions, in the coal, in this direction due to Lone Creek erosion having removed the mineable coal, although they also indicate the discharge to Lone Creek is minor. There are too few wells to confirm this observation, but 24D2 supports it and none of the wells contradict it.

The alluvial wells displayed the least variability, based on the standard deviation (Table 1). The sub red 1 sand wells were also steady. Most wells in the glacial till and mineable coal exhibited similar variability, although several specific coal wells had much higher standard deviation than the others (Table 1). Generally speaking, local aquifers would have more variability because they would respond more quickly to recharge. This would describe the glacial drift wells. The alluvium should also be a local aquifer but the intersection with the streams and the discharge from the glacial drift and mineable coal could stabilize the water level thereby decreasing the observed variability.

The groundwater level in the sub red 1 sand appears to be significantly lower than in the mineable coals, as noted by Riverside (2010, p. 4-22). Two well pairs demonstrate this. The level in the mineable coal is 765.3 and 582.1 ft amsl at well 22H and 22H1-U1, respectively (Figure 6). Similarly, the level is 762 and 685 ft amsl in the glacial drift and sub red 1 sand at wells 27G and 27G1U, respectively (Figure 6). The first well pair is about a mile northeast of the second pair, so they are not on the same flow path (from west to east) (Figure 5). Both suggest the existence of a downward gradient but neither indicates there is an unsaturated zone between the layers. The vertical gradient at 22H1-U1 indicates there is little hydraulic connection, meaning that pumping in the sub red 1 sand would likely not affect the levels above.

Groundwater levels in the glacial drift do not demonstrate a discernible slope because the glacial drift is eroded so these isolated aquifers discharge into the many channels and wetlands. The groundwater levels are generally higher than the surrounding stream elevations (Figure 6) so the flow is from drift to streams. Riverside (2010) notes the water levels are 8 to 72 feet below the ground surface and suggests the ponds and bogs are therefore not connected to the shallow groundwater. The standard deviation of water levels (Table 1, Figure 7) reflects the variability in water level in the glacial drift and indicates the water level rises and falls on the order of from 1 to about 6 feet on a regular basis. Variability could be due to variable recharge rates, with more recharge occurring in forested areas than in the bogs (Riverside, 2010). This change is about 5 to 20% of the saturated thickness.
Figure 5: Location of groundwater and surface water monitoring sites, Chuitna River and Lone Creek project area. Source Riverside (2009 and 2010). Base USGS 1:24000 DRG
Figure 6: Groundwater levels and surface water elevations. See Figure 5 for sources.
Chuitna River Project
Groundwater Level Variability
Expressed as Standard Deviation
Figure 7: Groundwater level standard deviation. See Figure 5 for sources.
Table 1: Groundwater level and standard deviation for wells with coordinates and level hydrographs in Riverside (2010, 2007).

<table>
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<tr>
<th>Alluvium</th>
<th>Count</th>
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<th>Std Dev</th>
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<tr>
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<td>29</td>
<td>637.3</td>
<td>0.69</td>
</tr>
<tr>
<td>25I</td>
<td>18</td>
<td>881.3</td>
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<td>28M</td>
<td>29</td>
<td>713.1</td>
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<tr>
<td>35H1</td>
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<tr>
<td>Glacial</td>
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<td>689.8</td>
<td></td>
</tr>
<tr>
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<td>848.1</td>
<td>2.32</td>
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<tr>
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<td>0.70</td>
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The groundwater level variability as represented by standard deviation does not exhibit obvious inherent trends around the site (Figure 7). There is not one area or another with more than the average variability. However, the standard deviation in the glacial drift is higher in the center of the areas at points furthest from the creeks. It is here that the recharge into the drift causes mounds. Meteoric water infiltrates the glacial drift and flows downward until impeded at which point a mound forms. The mound increases the gradient and transmissivity for flow into the channels. Baseflow increases due to increased gradient and transmissivity and then decreases as discharge to the creeks (baseflow) depletes the mound. Discharge from the glacial drift decreases as the mound drops and lowers the flow gradient, which in turn slows the rate at which the mound is depleting in a negative feedback that helps to preserve the lower baseflow levels. In other words, as the baseflow reaches its lowest rates, the storage supporting that baseflow deplete much slower than just after the mound has been filled.

Standard deviation of water levels in the mineable coal is about the same as in the glacial drift although several individual wells have a much higher standard deviation, exceeding 10 ft², and several are lower
with values approaching zero. This implies that more recharge reaches the minable coal than previously thought because seasonal changes cause variability. However, the highest standard deviation values are near the streams, in wells 06A2, 35A3, 19A1, and 20B1 which also have groundwater levels much above those streams. This area of high variability coincides with the point of transition from confined to unconfined aquifer, where it discharges to the alluvium; inherently, the water levels in confined aquifer wells are more variable because the water level changes more for the same amount of groundwater removal due to different storativity values. The higher standard deviation therefore does not reflect more recharge to the coal but rather the combined effect of changing alluvial water levels and groundwater storage properties in a confined aquifer.

Baseflow Yield

Baseflow is river flow that occurs when there is no runoff or interflow. It is strictly groundwater discharge and a true expression of the average recharge to the system (Myers, 2009; Cherkauer, 2004). In the Chuitna River basin, groundwater discharge supports the aquatic systems during the winter, from December through March, when other sources dry. The baseflow yield would be the baseflow expressed as a rate, such as in/y. This section considers the baseflow from the entire Chuitna River and then uses data (Riverside, 2009) to consider how the yield varies around the study area to determine the variability in recharge around the basin or in the formations discharging to the rivers.

The USGS gaging station CHUITNA R NR TYONEK AK (#15294450) operated continuously from 1975 through 1986. The flows are seasonal with annual flood peaks up to 4000 cfs and winter baseflow as low as 30 cfs (Figure 8). Flows most years exceed 2000 cfs, often multiple times. The average flow rate over that period has 359.4 cfs.
December through March flow has not exceeded 200 cfs for nine of the ten years (Figure 9). The exception, (1976-77) had flow as high as 800 cfs in early December (Figure 8), probably due to a major late fall runoff event; the following baseflow discussion does not include that year nor is that year included on Figure 9.

Flow generally decreases through the baseflow period starting in December, but the obvious spikes probably coincide with warmer melt periods. The hydrographs do not show simple baseflow recession. The year with the lowest flow, 30 cfs in 1979-80 very early in the baseflow period, also experienced flow over 150 cfs (Figure 9).

Ignoring 1976-77, the baseflow yield rate for the 130 square (sq) mile basin above the gage is 9.2 in/y with a range from 6.9 to 12.1 in/y. The average baseflow, not including 1976-77, was 89 cfs. Assuming that baseflow is a relatively constant portion of the hydrograph over the entire year, the baseflow yield rate is 25% of the average flow at the site. Because of both the significant variation in baseflow yield and the variation in runoff, the yield rate proportion probably varies substantially from year to year and season to season.

Temporary gaging stations have been established around the proposed mine site for various periods since 1983 (Figure 5) (Riverside, 2009). The gaging periods are inconsistent but generally have some overlap. Baseflow at each station was determined as the average December through March flow (Riverside, 2009, Table 3.6). The total baseflow from streams 2002, 2003, and 2004, the sum of baseflow for C110, C180,
and C220, equals 36.2 cfs. The three watersheds that drain the proposed mine site therefore provide about 41% of the baseflow to the Chuitna River above the Tyonek gage.

![Chuitna River nr Tyonek, AK](image)

**Figure 9: Baseflow for the Chuitna River nr Tyonek, gage # 15294450.**

The baseflow yield has a few trends and observations apparent on the distribution around the basin (Figure 10). With one exception, the baseflow yields range about the same as the annual distribution of yield at the gaging station (Figure 9). The uppermost stations with ten years or more record all yield more than the downstream sections, again with one exception. Upstream site C195 on Lone Creek yields 13 in/y from 5.8 sq miles over 16 years. Site C50, draining 3.8 sq miles in upper stream 2004, yields 13.46 in/y and site 128, draining 3.8 sq miles in upper stream 2003, yields 12.5 in/y. The downstream sites all yield less (Figure 10). In general, the yield drops about 2 in/y between the upper and lower portions of streams 2003 and 2004, which may simply reflect a decrease in precipitation with lowering altitude because glacial drift is the primary cover throughout.

An exception is the 17.14 in/y at site C198 on Lone Creek, which has ten years of record and drains 7.8 sq miles, 2 sq miles more than the upstream station C195. This is an increase of more than 4 in/y from that upstream station. The intervening reach may have a mineable coal outcrop into the alluvium that adds flow from outside the Lone Creek drainage. If the additional flow had resulted from recharge in the intervening 2 sq miles, the necessary rate would have been 29.2 in/y. If the intervening 2 sq miles had a yield equal to that at the upper gage, the additional flow would be 1.9 cfs. Therefore, the mineable coal is discharging approximately 2.3 cfs to the stream.
Figure 10: Baseflow Yield in the study site around the Chuitna River basin. See Figure * for the monitoring site names.
Discharge to Streams

Both channels 2002 (Lone Creek) and 2004 have multiple inflow and outflow areas (Figures 11 and 12). There is a complicated exchange of water through the hyporheic zone (Oasis, 2010), with water entering and leaving the channels. Based on both temperature readings and head gradients between the stream and near-stream groundwater, Oasis (2010) found a dynamic equilibrium between inflow and outflow. They also found some correlation with landforms, gradients, and other channel features. This complexity contributes to the necessary complex habitat heterogeneity necessary for the maintenance of biodiversity (Palmer et al, 2009). If the groundwater discharging to the alluvium changes in rate, volume, location, or temporally through the year, the discharge patterns to the creeks will also change. Changing the flow pattern to the alluvium will change this dynamic equilibrium. They had considered these micro-differences in an attempt to determine where to augment the stream flow.

Figure 11: Figure 3.1-9 from Oasis (2010) showing the location of seeps in stream 2002 based on temperature measurements.

Wetlands

Wetlands are physical features on the landscape that also have important hydrologic functions in regulating runoff and groundwater recharge and discharge (Bullock and Acreman, 2003; Winter, 1998);
the three hydrologic functions are intimately connected. Their function depends significantly on their location in the landscape (Figure 13). Wetlands that occur in valley lowlands and at toe slopes were considered discharge wetlands (HDR, 2008, section 3.2.4) whereas isolated wetlands on flat uplands were considered as recharge wetlands (HDR, 2008, section 3.2.5). An assumption apparently is that discharge to wetlands eventually becomes streamflow, but the mine studies are unclear about that (HDR, 2009). Wetlands on the floodplains or otherwise near the streams are not likely to be isolated, therefore assuming wetland discharge becomes stream discharge is justified. Evapotranspiration (ET) losses from wetland vegetation would draw from that discharge and represent a depletion of groundwater recharge before it becomes discharge. ET is not a factor during the winter when groundwater-sustained baseflow discharge is essential.
Figure 12: Figure 3.1-10 from Oasis (2010) showing seeps along stream 2004.
Floodplain wetlands are most important for regulating runoff because wetlands help store overbank flows and slow its return to the streams, which occurs either by runoff or interflow. They may not regulate baseflow during winter because the pathways – overland flow through wetland vegetation and shallow groundwater inflow – would be frozen. Floodplain wetlands may likely also be discharge wetlands. They may also be recharge wetlands to the alluvial aquifer, although the area of such wetland is likely very small based on wetland function proportions (HDR, 2008). Wetlands on floodplain discharge sites may receive discharge from the alluvium which originated as recharge in the glacial drift or mineable coal sequence. The focus of this study is on the recharge and discharge functions because they are most difficult to account for and to restore.

By far, the discharge dominates the wetland functions at the Chuitna Coal Mine site (HDR, 2009), with 42% of the wetlands (1646 acres) in the proposed mine area contributing this function. Only 1% (24 acres) of the wetland area contributes a recharge function. “Uplands are expected to recharge groundwater at a higher rate than wetlands, with wetlands contributing to groundwater recharge only when they are isolated from streams and found in flat landforms” (HDR, 2009, p. 23). The premise is that free-draining uplands should allow more recharge than wetlands that are not isolated and flat; this implies therefore that the recharge rate on the uplands is higher than an overall average rate because non- or slow-recharging wetlands would not contribute. This is similar to the findings of Bullock and Acreman (2003) that many headwater wetlands actually slow the recharge because they exist due to the fact that the underlying formation has low vertical conductivity. The statement by HDR is justified.

Mine proponents evaluate post-mining wetland functions by demonstrating that their grading and revegetation plans would reestablish the same amount of wetland function, based on vegetation and slope.
type (HDR, 2009, p. 3). They acknowledge that successful restoration is critical: “A critical underlying premise of this analysis is that the plans for restoration of post-mining topography, hydrologic features and characteristics, and establishment of vegetation are successfully implemented” (HDR, 2009, p. 1). Their assessment of the potential reclamation of the proposed mine site is analysis of “a hypothetical scenario of the geographic pattern of reclamation wetland communities” (HDR, 2009, p. 4). For the analysis of post-mining conditions, “scientists draped vegetation communities over the post-mining landforms in proportions and patterns similar to those found in the baseline condition” (HDR, 2009, p. 17). The “draping” was a hypothetical GIS exercise that assumes they will successfully restore the wetlands just as they existed prior to mining. Apparently, mine proponents assume that wetland function at a point can be restored and then extrapolate that assumption to the whole mine site. Using GIS, they argue the recharge function will be the same as existed prior to mining.

Assumptions that the wetlands can just be recreated are fallacious without evidence proving it can be done. The National Academy of Sciences (NAS) (2001, p. 25-27) concluded that vernal pools, fens, and bogs were the most difficult to restore. All three of these types describe the wetland systems present in the Chuitna watershed, but bog may be most accurate. Bogs occur on peat soil which requires millennia to establish. As described, wetlands are much more than a recharge or discharge point for groundwater, and the findings of the NAS indicate that this aspect of mine reclamation will likely fail. Unlike most of the studies where restoration consists of rewatering a dewatered wetland or minor recontouring, restoration from surface coal mining where the wetlands are part of the overburden, such as in the Chuitna watershed, involves creating the wetland from scratch and has not proven possible in the past.

**Hydrogeologic Properties of the Formations**

Most recharge enters the system through the glacial drift. Much of the discharge is from the glacial till to the alluvium to the river/tributaries. The glacial drift ranges from 40 to 140 feet thick with measured conductivity from 10 to 300 ft/d (Arcadis, 2007, p.4). (Their Table 3 shows “K observed” ranging from 0.05 -330.0 ft/d.) Arcadis calibrated three glacial drift model zones to have horizontal conductivity equal to 1.5, 8.0, and 50.0 ft/d, respectively, and vertical conductivity equal to 0.15, 0.16, and 1.0 ft/d. Unfortunately, there are no measurements with which to compare the vertical conductivity. Based on my modeling experience, the relatively high calibrated vertical anisotropy\(^3\) was required to match the observed mounds in the water table. Lower horizontal conductivity would also cause the mounding but the saturated thickness decreases near the points of discharge so that the lower conductivity may have made calibrating the appropriate discharge more difficult.

The alluvium is up to 40 feet thick (Arcadis, 2007, p. 4) and therefore stores substantial amounts of water before it reaches the river; Arcadis estimates the conductivity would range from 30 to 300 ft/d, based solely on grain size distribution (\(\phi_d\)). Based on percolation tests, Arcadis (2007, Table 3) noted that observed conductivity is 0.25 to 4.22 ft/d. Their calibrated values for two model zones were 300 and 20 ft/d, much higher than the percolation tests. This is not unexpected because of scale issues; a percolation test is a point measurement whereas model calibration is over a larger area which usually has larger

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3 Vertical anisotropy is the ratio of the horizontal to vertical hydraulic conductivity. Very low values indicate the horizontal conductivity is much higher than the vertical, which means little vertical flow will occur through the formation.
conductivity (Schulze-Makuch et al, 1999). Large-scale conductivity is often much higher than point measurements when the aquifer is highly heterogeneous.

Arcadis reported the observed horizontal conductivity for the mineable coal sequence ranges from 0.00028 to 14 ft/d, a huge range, and calibrated it to equal 0.01 with the vertical conductivity equal to 0.0009. The low vertical anisotropy is due to the conceptualization that most of the recharge ends up in the glacial drift with little vertical movement to lower layers. The low vertical conductivity backs up the infiltrating water, preventing much of it from entering the mineable coal, so that it flows horizontally through the glacial drift to the streams and alluvium. The relatively high horizontal conductivity allows for through-flow from west to east of the study site, with some discharging into Lone Creek. Both conductivity magnitudes are similar to that found for the coal/sandstone sequences by Myers (2009).

Above I estimated that 2.3 cfs (198,720 ft³/d) discharged from the mineable coal to the Lone Creek alluvium and eventually to the creek. The width between gages would be about 2 miles, so the flow cross-section would be 2 miles times the effective aquifer thickness, or 2*5280*t, or 10,560t ft³. In the mineable coal, Riverside (2010, p. 4-23) indicated the gradient is flatter on the west and increases to the east (.015 to .19 ft/ft). Applying the higher value, transmissivity, T, would equal (198,720/(10,560*.19)), or 99 ft²/d. For a cross-sectional thickness varying from 10 to 100 ft (it is unknown without further analysis), the conductivity varies from 0.99 to 9.9 ft/d. This is well within the reported measured range but much higher than Arcadis’ calibrated value.

The observed conductivity in the sub red 1 sand ranges from 1.8 to 8.0 ft/d (Arcadis, 2007, Table 3), which indicates it could pass significant amounts of flow. They calibrated it in two zones as 1.0 and 20.0 ft/d, but the vertical conductivity is extremely low, at 0.00002 ft/d. This low value prevents the recharge on the site from sinking into the deeper layers but allows most any amount to pass through from west to east without discharging to the creeks. Because this layer would likely not be disturbed by mining, the accuracy of the estimate does not have much significance to the conceptual model for the site.

The gradient between “upgradient well (27G1U) and down gradient well (24D2) is 0.013” (Riverside, 2010, p. 4-21). Used with transmissivity (300 to 1800 gpd/ft, p. 4-4), the flow could range from 211,000 to 1,270,000 ft³/d over a mile wide section of the red sands aquifer (1774 to 10,640 af/y).

**Groundwater Quality**

The analysis here deals primarily with flows and the ability to reconstruct those flows, not the groundwater water quality. However, most analysis suggests the groundwater is mostly compartmentalized with little water seeping from the glacial drift to the mineable coal. If so, there could be differences in the groundwater type among aquifers.

Based on chemistry reported in Riverside (2010), all formations are of the calcium bicarbonate type, with slightly less calcium in the sub red 1 sand. Although this does not prove the groundwater mixes among aquifers, it suggests the source of the glacial drift and alluvium is the same as that of the mineable coal. This could result from the erosion, both fluvial and glacial, of the Tyonek formation providing the source material for the drift and alluvium.
The mineable coal sequence groundwater exceeds aquatic life, and occasionally drinking water, standards much more often than does the groundwater in the glacial drift. The parameters commonly exceeded by minable coal groundwater include aluminum, arsenic (drinking water standard), cadmium, copper, iron, lead, manganese, nickel, silver, and zinc (Riverside, 2010, Table 5-20) while the groundwater in the glacial drift exceeds standards for iron, lead, manganese, and silver (Riverside, 2010, Table 5-14). It is probably not possible to distinguish the source of the contamination between the coal and the interburden, but backfilling the overburden would likely increase the contaminant load. This could occur, at least temporarily, because the previous structure of the interburden would have been broken by the mining process. Baseflow initially after backfill would have higher contaminant levels.

**Summary of Conceptual Flow Model**

The hydrologic and geologic data reviewed for this study reveal a remarkably diverse and complicated flow pattern affecting baseflow in the study area streams as reflect in the flow and groundwater data for the three mine site area streams – 2002 (Lone Creek), 2003, and 2004 – reviewed in this study. Mining would affect streams differently, depending on whether mining excavates the stream or simply the flowpaths to the stream. Restoration faces many obstacles because the hydrology complexity must be restored in order to restore the baseflow hydrograph, in all of its variability. Mining would also affect the entire Chuitna River baseflow. For example, considering the proposed Chuitna Coal Mine, the three mine site streams produce about 41% of the river’s baseflow.

Two groundwater flow systems, the glacial drift and the Tyonek formation, which consists of the mineable coal sequence and the sub red 1 sand, control the baseflow in the study area streams. Inflow to the system is both recharge through the surface, which in the study area is primarily the glacial drift, and flow from offsite west to east across the site through the minable coal and sub red 1 sand. The glacial drift forms a sequence of local aquifers that form groundwater mounds during recharge events and discharge groundwater to nearby streams throughout the year; the recharge replenishes the storage which discharges subsequently to the streams. The mineable coal passes flow from west of the Chuitna River to discharge into stream 2002, Lone Creek, because this creek eroded into the Tyonek formation.

Baseflow depends on recharge rates that vary temporally and across the watershed and heterogeneous properties of the wetlands, soils, and glacial drift. It also depends on a relatively impermeable layer, the minable coal, preventing the recharge from draining too deeply. Additionally, baseflow requires a layer beneath the glacial drift with sufficient transmissivity and connectivity with upstream sources to pass groundwater from offsite to stream 2002. These hydrologic properties control the rate at which the recharge becomes discharge and therefore the rate the baseflow recedes.

The glacial drift is extremely heterogeneous. Silt and clay substantially control the conductivity and the ability of an aquifer to hold and release groundwater, but the proportion of silt and clay varies immensely over the study area. This variation, which is mostly random, causes heterogeneity in the hydrologic properties and varying gradients and transmissivity along the flow path. Average properties estimated in groundwater models or found from tests do not begin to replicate the in situ complexities.

Storativity is the amount of water released for a given decrease in the potentiometric surface or water table. Because clay and silt control the size of the pore spaces, and generally the pore spaces control the
rate that water is released from storage, the variable silt and clay proportions indicate that the amount of water released from storage varies significantly around the site. The variable rate that aquifers release water from storage adds further variability to the baseflow recession.

Recharge around the site has been shown to vary by about a factor of two, from about 6 to 13 in/y. However, recharge as determined at a point is an average over all of the small recharge units upstream in the watershed. Recharge at a point depends on the soils, the underlying glacial drift properties, and the presence and type of wetland on the surface. As noted, non-wetland glacial drift likely has much higher recharge because it is free draining. Conversely, isolated wetlands allow recharge, but more slowly because of the low vertical conductivity which prevents them from quickly draining. These wetlands store water on the surface and provide recharge after the free-draining areas have dried. Therefore, recharge rates are actually an agglomeration of highly variable recharge components across the landscape. The thickness and properties of the unsaturated zone beneath the wetlands also control the rate at which water seeping through the ground surface actually reaches the aquifer.

The factors controlling baseflow discharge to the streams are highly variable across the site. The combination of recharge rates that vary around the watershed with variable unsaturated zone properties with variable properties in the glacial drift saturated zone controls the actual baseflow to the streams. Groundwater inflow to the streams has been shown to be highly variable within individual stream reaches and along the stream lengths. It is this complexity along the stream to which the aquatic habitat has adapted (Vannote et al, 1980; Winter, 1998).

This complexity must be restored if the aquatic habitat in the streams affected by mining is to be restored. The immediate effects depend on whether a stream is excavated or is affected in other ways. The proposed Chuitna Coal project would excavate stream 2003 and remove about half of the watershed and glacial drift and minable coal aquifers for stream 2002 and 2004 (Lone Creek). All of the streams in the study area receive baseflow from variable recharge through the heterogeneous glacial drift which would be totally removed by stripping to reach the mineable coal. The mineable coal prevents the recharge from draining vertically away from the glacial drift and provides a significant discharge of water to stream 2002, likely from outside the project area.

Palmer (2009) states that a database which documents over 38,000 restoration projects does not contain a single case in which a rebuilt stream fully compensated for the ecological functions lost when a stream was destroyed. As she noted: “Contrary to suggestions made in the mitigation plans, the very concept of creating streams with levels of ecological function comparable to natural channels on sites that have been mined-through … remains untested and quite unlikely to succeed” (Palmer, 2009, p.). Even if the stream cross-section can be made to resemble some stream type, the low flow characteristics dependent on heterogeneous groundwater inflows and small-scale water (and nutrient) exchange between the stream and hyporheic zone cannot be restored (Palmer et al, 2009). In the proposed Chuitna Coal Mine project site, the detailed small-scale water exchange documented by Oasis (2010) cannot be restored.

Therefore restoration must replicate several aspects of the existing conditions – the distribution of soils and wetlands across the landscape, the variability in hydrologic properties in the glacial drift, and the relative impermeability to vertical flow present in the coal seams. The baseflow hydrograph in affected streams, not just an average baseflow rate, must be replicated. If the initial rate is too high, the
groundwater storage may drain too quickly so that the rate at the end of the period could be too low to support the aquatic habitat. If the aquifer stores too little water, baseflow throughout the period will be too low. Alternatively, too much recharge or too much groundwater storage would cause the baseflow to be too high which may disrupt the sediment and temperature conditions in the stream. It is essential to replicate both the average and range in baseflow to restore aquatic habitat. Because of the variable recharge and heterogeneous aquifers which must be restored to replicate the baseflow, it is not possible that a mine site can be restored so that the habitat which is dependent on the baseflow can be similar to its pre-mine value.

References


PacRim Coal, 2006. Chuitna Coal Project Geology Baseline Information.


INTEGRATED HYDROLOGIC EFFECTS OF CLIMATE CHANGE IN THE CHUITNA WATERSHED, ALASKA

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CITATION


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ABSTRACT

The main objective of this study was to assess the potential impacts of climate change on the Chuitna watershed hydrologic system. To do so, available geology, soils, climate, surface and groundwater and vegetation data were used to develop a 3-dimensional integrated conceptual flow model of the surface and subsurface flow system within the Chuitna watershed. Based on this conceptualization, a fully integrated hydrologic numerical flow model was then developed for the entire Chuitna watershed using the MikeSHE/Mike11 hydrologic code. We used this model to simulate surface and subsurface hydrologic conditions using spatially distributed air temperature, precipitation and reference evapotranspiration at 3-hour intervals for a historical base case period (1980 to 2000). The model was calibrated against spatially distributed snowpack, streamflow and groundwater depth data over multiple years.

To assess the range of future climate change impacts on system hydrology, we used modeled maximum, minimum and median air temperature and precipitation projections from the International Panel on Climate Change (IPCC) for the A1B emission scenario to develop five seasonally-variable climate scenarios for the Chuitna watershed. Results suggest that for even the minimum projected increases in air temperature and precipitation, significant changes in hydrology are projected to occur in the Chuitna watershed for the 2080 to 2100 time period. Much of the projected changes to the system can be attributed to temperature-driven increases in actual evapotranspiration (AET) and changes in the snowpack. Average annual AET is projected to increase by 10% to 46% in lower watersheds and by 14% to 58% in upper watersheds. Across all climate scenarios, average annual snowpack is projected to decrease by 40% to 95% with an average decrease of 62% across all sub-watersheds in the system. By the end of the century, snowpack is projected to accumulate 1-2 weeks later and to melt out 1 to 3 months earlier. Such changes in the quantity, timing and duration of water inputs to the system result in seasonal impacts to soil moisture, groundwater recharge, and both surface runoff and baseflow to streams. As a result, winter streamflow is projected to increase by 43% to 640% and summer streamflow is projected to decrease by 7% to 73% across the Chuitna watershed for all climate scenarios. Projected changes in spring and fall streamflow are more uncertain yet often show significant changes from historical conditions.
INTRODUCTION

The Chuitna (Chuit River) watershed is located about 45 miles west of Anchorage on the northwestern side of Cook Inlet near the Native Village of Tyonek and the community of Beluga (Figure E-1). It is an important ecosystem that supports five species of Pacific salmon, several species of resident fish and a variety of wildlife such as moose, brown and black bears, wolves, beavers, bald eagles and numerous other species of migratory birds. The watershed consists of a large network of nearly 200 miles of streams that drain about 150 square miles into Cook Inlet. Factors affecting streamflow within this ecosystem are complex and strongly influenced by seasonal changes in climate and dynamic interaction with the groundwater flow system. Groundwater flows are critical to salmon habitat because they cool surface waters in warm months and heat them in cold months. Salmon spawn, rear and overwinter in areas with groundwater upwelling or downwelling which provide oxygenated water at temperatures conducive to development and survival of eggs and juvenile fish (Groot and Margolis, 1991). Because of climate change associated impacts in Alaska, such as wetland drying, rapid glacial retreat, increased bark-beetle infestations and fires, concerns are mounting about similar impacts of climate change on these sensitive hydrologic systems that are fundamental to the integrity of the entire watershed ecosystem.

By the end of 2100, global climate models project that both air temperature and precipitation will increase significantly in southcentral Alaska. The magnitudes of projected changes however depend on many factors and vary seasonally. For example, air temperatures during winter periods are projected to increase between 4°C and 10°C, while precipitation may increase from 6% to greater than 50% over present day conditions based on global climate model results for a “moderate” greenhouse emissions scenario (Christensen et al., 2007). Projected changes in climate will translate into hydrologic changes through alteration of rain and snowfall timing and intensity, evapotranspiration and groundwater and surface flows.

Figure E-1. Chuitna watershed and sub-watersheds in southcentral Alaska
Land-use changes are also expected to change the hydrology of the Chuitna watershed. In the 1960s, oil companies explored the Tyonek Formation of the Kenai Group within the lower watershed area for hydrocarbons. By the mid-1970s coal companies began exploring the extensive coal seams along the middle of the watershed, in the southern part of the Beluga Coal Fields. The PacRim Coal, LLC mining company (PacRim) is currently pursuing a permit to extract approximately 300 million tons of coal from what would be Alaska’s largest open-pit coal mine (~5,000 acres). Part of PacRim’s proposed plan involves removing about 11 miles of salmon spawning and rearing habitat during a 25-year mining operation. Although the preliminary reclamation plan indicates that the surface of the mined area will be reconfigured similar to pre-mining conditions, concerns have been raised about impacts during mining and post-reclamation on the system hydrology and ecology, especially combined with effects of future climate change. PacRim conducted local baseline characterizations of surface and groundwater hydrology around the proposed mine area, but did not develop an integrated understanding of how the surface and groundwater interact within the watershed. This is important because to fully understand how climate change or mining/mine reclamation impacts the system hydrology, especially downstream of the mine, the integrated hydrologic flow system must be well understood.

The main objective of this study is to assess the potential impacts of climate change on the Chuitna watershed hydrologic system (see Figure E-1) using a physically-based, fully-distributed parameter integrated hydrologic model. This study differs from other climate studies in two ways; it attempts to bracket the range of hydrologic changes given uncertainty in global climate scenarios simulations, and it focuses on detailed changes in hydrologic processes. A secondary objective is to outline a general approach and methodology to investigate climate change in other hydrologic and ecological systems in Alaska. To meet the second objective, a full documentation report was prepared which systematically outlines the steps involved in developing and applying a fully integrated hydrologic model (Prucha et al., 2011).

**APPROACH AND METHODS**

To simulate future hydrologic conditions in the watershed due to climate change, a mathematical model of the current integrated system (basecase) was constructed. This was done in several steps following industry standard techniques (Refsgaard, 1997, Anderson et al, 1993).

**Characterization of the Surface-Subsurface Flow System:** Publically available data obtained from various sources were incorporated into a digital database or a Geographical Information System (GIS; ArcGIS 10, ESRI Inc.) to facilitate spatial analysis. Mining consultants have collected extensive physical, chemical and biological data since the early 1980s, but have only made selected data publically available, and generally only in summary tables. Thus, the model developed in this study may differ from modeling results produced by the industry.

Below are some of the key data that were reviewed for this study (Prucha et al.2011) and added to the database/GIS.
• Surface and subsurface hydrologic data
  o detailed stream drainage networks (National Hydrologic Dataset), daily streamflows
    at a number of gages (Riverside, 2007 and 2009) and snowpack measurements
  o groundwater well construction data and levels (Riverside, 2007 and 2010)

• Climate data including climate station data for the proposed mining area (Riverside, 2009) and a 20-year, 3-hourly time-series of climate variables including precipitation and air temperature from the North American Regional Reanalysis (NARR, Mesinger et al., 2006). NARR data are available from NOAA/OAR/ESRL PSD in Boulder, Colorado, at http://www.esrl.noaa.gov/psd/data/narr/).

Conceptual flow model: Based on the surface-subsurface geologic and hydrologic characterization, a conceptual flow model of the entire integrated hydrologic flow system was developed that describes flow into, out of and within the watershed (Figure E-2). Specific processes described in the conceptual flow model include snowmelt, overland surface runoff, subsurface flow processes such as infiltration, evapotranspiration, groundwater recharge, groundwater flow and stream flow. This conceptual flow model was then used as the basis for the numerical flow model, which allowed us to determine how climate-induced changes in precipitation and temperature quantitatively alter the hydrology of the Chuitna watershed.

In the present-day system (basecase), precipitation occurs as rainfall during the summer months and snowfall during winter months. The more than 800 meter increase in topographic elevation of the watershed from Cook Inlet (southeast) to Capps Plateau (northwest) results in the doubling of precipitation and a drop in average annual air temperature of more than a 4°C(Figure E-3). As snow melts, it either becomes surface runoff (also known as overland runoff), or infiltrates into the ground. As water infiltrates into the ground, a portion typically flows downward in a partially saturated state through the unsaturated zone as unsaturated flow, until it reaches the groundwater table where it becomes groundwater recharge. In the unsaturated zone, roots extract the remaining soil water as plant transpiration. Water is also lost to the atmosphere from surface soils through soil evaporation. The combined process of soil evaporation and plant

![Figure E-2. Conceptual watershed-scale hydrologic flow model showing flow processes and general configuration](image-url)
transpiration is evapotranspiration. In the model, this term also includes the loss of water from open water bodies, snow sublimation and evaporation from the plant canopy. All precipitation in a natural system is lost through either evapotranspiration to the atmosphere, or via streamflow or groundwater discharge out of the watershed.

As groundwater is recharged, groundwater water levels rise and cause the water table gradient to increase towards streams. This increases groundwater discharges into streams and is termed baseflow. The combination of baseflow and overland flow produces streamflow.

The majority of streams deeply incise permeable Quaternary fluvio-glacial deposits that occur throughout the Chuitna watershed, which is typical of a streamflow system dominated by baseflow (Figure E-3). Within the proposed mine area, these deposits overlie a thick bedrock sequence, thousands of meters thick, comprised of alternating, lower permeability, laterally extensive coal seams and alluvial-plain deposits (interburden deposits) that vary from low permeability claystone/siltstone (overbank-floodplains) to more permeable sandstone conglomerate (former braided streams). Groundwater flow within the bedrock hydrostratigraphic units is complicated by substantial vertical (tens to hundreds of meters) and lateral offsets (5 to 26 kilometers) along steep-angle faults that traverse across the watershed; two of these faults extend hundreds of kilometers and are associated with the larger tectonic setting of southcentral Alaska. Groundwater within the bedrock units becomes increasingly confined with depth due to the relatively low permeability of interburden deposits. Although some groundwater drains from the bedrock into streams near the proposed mine, where the overburden has been removed by erosion, the calibrated flow model shows that streamflow is dominated by baseflow discharge from the shallow unconfined aquifer in the Quaternary fluvio-glacial deposits. The faulting and bedrock flow and discharge appear to have limited effects on the current undisturbed coupled shallow groundwater aquifer and streamflow system. However, these features will likely have a much more pronounced effect on the hydrologic system during and after excavation in the proposed mining area.

Overland flow is generated in hydrologic systems in two primary ways. When precipitation intensities exceed the soil infiltration capacity, water ponds at the surface and then flows down the slope as Horton flow, or Infiltration-Excess. Alternatively, when the ground surface saturates from below, typically through rising shallow groundwater, surface runoff can also occur as Dunne flow, or Saturation-Excess, typically near streams (green area on Figure E-2). Over the late-spring/early-summer season, snowmelt provides a constant source of saturation excess near streams. Within the Chuitna watershed, our model simulations show that overland flow to streams occurs through the Saturation-Excess rather than Horton flow because precipitation rates are low relative to calibrated soil hydraulic conductivity values. For example, a 100-year, 1-hour duration maximum storm intensity for the Anchorage area is 0.55 in/hr (USKH, 2006) which translates to 3.9E-06 m/s and is less than the lowest soil hydraulic conductivity value (4.0E-06 m/s). All rainfall events simulated have a much lower intensity than the 100-year storm, which effectively prevents Hortonian flows from being generated, and promotes saturation excess runoff.

The combination of vegetation and soil hydraulic properties within the watershed promotes infiltration rather than surface runoff in non-riparian (upland) areas. Vegetation coverage is high.
Groundwater levels in the Sub Red 1 Sand drop across faults. Upward flow occurs when confining pressures upgradient of faults increase (artesian conditions) relative to overlying aquifer heads (i.e., shallow glacial aquifer).

Most streamflow is discharge from shallow glaciofluvial/alluvium deposits. Inflow more from uphill side.

Precipitation Increases - more than doubles from Cook Inlet to Upper Watershed boundary

Air Temperature decreases with elevation (Snowpack larger and stays longer)

Evapotranspiration Increases - causes increasing water loss to the atmosphere

Figure E-3. Conceptual flow model for the Chuitna watershed
Integrated Hydrologic Effects of Climate Change in the Chuitna Watershed, AK

throughout the watershed; more than 50% is short shrub/scrub (upper drainages) and nearly 40% is deciduous (lower drainages), and 6% are wetlands. More than 700 ponds and lakes cover about 2% of the entire Chuitna watershed and represent local areas where overland runoff accumulates and possibly interacts with groundwater, though this has not been confirmed by field testing. High amounts of organic matter (i.e., peat) in surface soil also promote infiltration of snowmelt or rainfall due to their high soil water retention characteristics.

**Numerical Integrated Flow Model:** We used the physically-based, distributed parameter, integrated hydrologic software code MikeSHE/Mike11 (Danish Hydraulic Institute) to develop the hydrologic flow model of the Chuitna watershed. This code is used extensively worldwide in a broad range of water resource applications that range from river basin and wetland management/planning to ecological impacts assessment. It has also been used to study integrated hydrologic systems affected by land use modifications and climate change. It was selected for this study because it simulates all of the key hydrologic processes in the watershed described in the conceptual model, including:

- snowmelt using a modified degree-day snowmelt model,
- 1-dimensional unsaturated zone flow using full Richard’s equation (Graham and Butts, 2005),
- actual evapotranspiration (AET) calculated as a function of soil properties, plant community type and rooting depths, and a reference evapotranspiration (RET) calculated based on external climate variables including net short- and long-wave solar radiation, wind speed, vapor pressure, precipitation and air temperatures (Kristensen and Jensen, 1975). The RET is calculated externally using the FAO56 Penman-Monteith method (Allen, 2000).
- fully hydrodynamic streamflow using St. Venant flow equations that allow for wave propagation and backwater effects,
- fully 3-dimensional groundwater flow, and
- two-dimensional diffusive-wave overland flow to streams.

**MODEL CALIBRATION**

We calibrated this model against several years of available snow depths, streamflow measurements and groundwater levels at a 3-hour time step using NARR derived precipitation, air temperature and reference evapotranspiration (Messinger et al., 2006) that vary spatially with elevation. A detailed description of model calibration results is presented in the Documentation Report. Here we present calibration results only for streamflow.

The model reproduces observed snow depths at different elevations throughout the year, average groundwater levels, and captures key characteristics of streamflow at gauges located within different sub-watersheds, including baseflow, streamflow ascension/recession curves, and peak flows and volumes. Simulated streamflow characteristics at the different gages reproduce those in the observed hydrographs reasonably well (Figure E-4). Although higher correlation coefficients are typically required for watersheds that are well gauged, an average correlation of ~55% was achieved across the Chuitna watershed. The range is 6 to 76% or 45% to 76% excluding gage 180 along Stream 2003. It is unclear why the correlation is poor at gage 180, but
simulated flows are lower than observed (peaks and spring runoff). This may be due to errors in streamflow measurements at gage 180, under specifying precipitation, over estimating evapotranspiration, incomplete stream network data or using a surface topography that does not capture localized lateral surface drainage contributions into the mainstem 2003 stream. Despite the lower levels, the model is able to reproduce the two key runoff events (spring snowmelt and fall rains), and is also able to simulate the slow recession curves that appear to be generated by baseflow, rather than surface runoff (weeks to months long). Baseflow is simulated well in all of the gages (see Documentation Report), which is largely dictated by the slope of hillslope topography and lateral saturated hydraulic conductivity in the glacial deposits. Simulated baseflow decreases with elevation, similar to the observed flows.

The model was not calibrated to simulate highly accurate system state variables (e.g. stream depth) at specific points in the Chuitna because this depends on the accuracy of local stream cross-sections, which were unavailable for the watershed.

Figure E-4. Daily simulated (black lines) and observed (red dots) streamflow at gage 230 (upper panel) and gage 180 (lower panel) in the Chuitna watershed. Enlargements highlight timing and duration of spring runoff events.
CLIMATE SCENARIOS

We developed five future climate datasets reflecting projected changes in precipitation and air temperature projected for the late 21st century. Climate change projections for Alaska were extracted from a suite of 21 General Circulation Models (GCMs) run using the A1B emissions scenario (Figure E-5) from the Intergovernmental Panel on Climate Change’s Fourth Assessment Report (Table 11.1 in Christensen et al., 2007). To evaluate how Chuitna watershed hydrology responds to the broad range of future climate changes predicted by the GCMs, we chose combinations of the maximum and minimum predicted changes in air temperature (Tmax, Tmin) and precipitation (Pmax, Pmin), as well as the median changes in both (T50/P50; Figure E-6).

Though changes in air temperature and precipitation used for each hydrologic model scenario are not simulated by the same GCM model, the extent of hydrologic impacts caused by the range of GCM predictions can be assessed as well as the independent effects of temperature and precipitation changes. Further, the changes projected for the late 21st century in our T50/P50 scenario are the same as those predicted for mid-century under the Tmax/Pmax scenario.

Future climate data series for the Chuitna watershed were prepared by applying seasonally specific changes in temperature and percent changes in precipitation for each of the five scenarios outlined above to the baseline (1980 to 2000) 3-hour time-step NARR data. Often referred to as the “delta method” (Hamlet et al., 2010), this method is simple to implement and preserves the sequence of weather and natural climate variability in the baseline data. The timing and magnitude of extreme climatic events (e.g. intense storms) may change in the future; however, such projections do not currently exist for this region and would be highly uncertain if they did.

Climate change scenarios were seasonally-specific (Figure E-6), with the largest temperature changes occurring in the winter (December through February) and the smallest in the autumn (September through November). Winter is also projected to experience the largest relative changes in precipitation. Evapotranspiration (ET) is another critical external climate variable that strongly influences watershed response to climate change because it is a function of both temperature and precipitation. Increased future air temperature affects hydrology through increased snowmelt resulting from convective air heating (sensible heat), warmer temperatures resulting in rain instead of snow, and increased water loss via ET.
### Projected Temperature Increase

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### Projected Precipitation Increase

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Figure E-6. Five climate change scenarios for Alaska at the end of the century (2080-2099) derived from 21 GCMs for the moderate A1B emissions scenario (Christensen et al, 2007). Projected changes in Temperature (T) and Precipitation (P) were used to adjust historical baseline climate data (NARR; Messinger et al. 2006) to create future climatologies.
RESULTS OF MODEL CLIMATE CHANGE SIMULATIONS

Change in Snowpack

Baseline snowpack in the Chuitna watershed is greatest in the upper reaches and lowest near the coast (Figure E-7). Snow depths increase from mid-October, peak in early April (Lower Chuitna) to mid-May (Upper Chuitna) and melt-out by mid-May (Lower Chuitna) to late June (Upper Chuitna). In the upper Chuitna watershed, the maximum snow water equivalent (SWE) approaches 1000 mm, while in the lower watershed it is less than 200 mm. The spatial variation is primarily due to orographic effects on temperature and precipitation.

In all future scenarios, average annual snowpack decreases and snowmelt increases (Figure E-7), despite minor (Pmin) to significant (Pmax) projected changes in precipitation. For scenarios with the lowest increase in temperature (Tmin), the projected decrease in average annual snowpack for the entire Chuitna watershed is 19% to 46%, relative to the basecase. For the Tmin scenarios, inter-annual variability of winter snowpack increases. In some years the snowpack is projected to exceed historic baseline conditions and, in other years, the snowpack is greatly diminished as it may melt out intermittently throughout the winter (see Documentation Report). Under scenarios with the greatest temperature increase (Tmax), the model projects the virtual elimination (86% to 90%) of the historically continuous winter snowpack (Figure E-7). In the Tmax scenarios, snow accumulates in a series of smaller snowpacks that melt-out every few weeks. The decrease in snowpack relative to the historical baseline is greatest at lower elevations where annual snowfall is lower and air temperatures are higher, indicating that melting thresholds are reached sooner at lower elevations (Figure E-7). The difference in change in snowpack relative to the historical basecase is projected to be least for the Tmin/Pmax scenario (-40% Upper Chuitna; -85% Lower Chuitna) and greatest for the Tmax/Pmin scenario ≥-95%)

Another significant change projected by our model is that the start and end of the snowpack also change due to the climate changes (Figure E-7). For all scenarios, the start of the snowpack is projected to be delayed in most years between 1 to 2 weeks. Break-up, or the melting of the snowpack, begins on average 1 to 3 months earlier than the basecase (Figure E-7), depending on the elevation and scenario. For example, spring snowpack is projected to be reduced by approximately 100 days for Tmax scenarios, approximately 60 days for the T50P50 scenario, and approximately 40 days for Tmin scenarios. Under all scenarios, there are likely to be an increased number of rain-on-snow events as well as intermittent melt-out events during winter.

Change in soil moisture

The soil moisture content at any moment in time at any point within the model is quite variable because it depends on a number of spatially-variable factors such as vegetation, soils, groundwater depths, snowmelt, surface topography and climate. The historical basecase model results show that soil moisture content varies most in surface soils (Figure E-8) because of the direct net effect of precipitation, snowmelt, soil evaporation and plant transpiration. Variation in soil moisture decreases rapidly with depth as the effects of these surface processes diminish. Depending on the location, surface soils saturate during spring snowmelt (June for the Upper Chuitna area “A” and May for the Mine area “B”), de-saturate during the summer (early-August
Figure E-7. Simulated average daily snow depth (mm SWE) for three locations in the Chuitna watershed. At each location, future snow depth was modeled under five climate change scenarios. Elevations are A) 512 m, B) 216 m, and C) 15 m.

for Upper Chuitna area “A” and late June for Mine area “B”) and then re-saturate during fall rains by September.

Future climate change is projected to affect surface soil moisture contents primarily through the dramatic shift in snowmelt (Figure E-7). Surface soil moisture contents for all future scenarios are higher than the historical basecase for winter months (from November through about the end of March; Figure E-8) due to increased snowmelt caused by increased winter temperatures. However, from March to mid-summer, moisture contents are projected to decrease compared to the historical basecase. The timing of minimum summer soil moisture content shifts from late-June at the mid-watershed mine location (“B”), to about mid- to early-June (2 to 4 weeks earlier) and from late-July in Upper Chuitna (“A”) to late- to early-June (1 to 2 months).

The deviation of soil moisture content from baseline conditions is also greater in the Upper Chuitna area, which suggests upper watershed soils are more sensitive to climate changes. One reason for this may be because lower soil permeability in the upper watersheds cause slower infiltration of precipitation, which increases loss of soil moisture via evapotranspiration. Soil moisture content decreases most for the TmaxPmin case because the increase in precipitation is insufficient to offset the increased “drying” effect due to increased AET caused by increased temperatures. Soil moisture content decreases the least in the TminPmax case because the increase in precipitation is highest relative to the increase in temperature. The changes in shallow soil moisture contents may cause increased stress on vegetation, which may in turn exacerbate current problems like wetland drying, insect outbreaks, or forest fires.
Projected effects of climate change on soil moisture content decreases with depth (see Documentation Report). This is because the effects of plant transpiration and soil evaporation at the ground surface decrease with depth. At one meter depth, simulated soil moisture during summer decreases approximately 10% in the upper Chuitna watershed “A” and increase by approximately 5% in the Mine Area “B” of the Chuitna watershed.

![Simulated average monthly surface soil moisture for two locations in the Chuitna watershed for a historical basecase and five climate change scenarios. Elevations are A) 512 m and B) 216 m.](image)

**Figure E-8.** Simulated average monthly surface soil moisture for two locations in the Chuitna watershed for a historical basecase and five climate change scenarios. Elevations are A) 512 m and B) 216 m.

### Change in Actual Evapotranspiration (AET)

Simulated baseline AET in the Chuitna watershed decreases modestly (~10%) from the Lower Chuitna (~25 in yr⁻¹) to the Upper Chuitna (~22 in yr⁻¹; see Documentation report). Seasonal AET patterns are similar to changes in air temperature, with lowest values occurring during the winter (< 1 mm day⁻¹) and highest values during June (>8 mm day⁻¹). Simulations of historical conditions indicate that AET as a percent of annual precipitation decreases with increasing elevation, from 76% in the Lower Chuitna to 31% in the Upper Chuitna (see Documentation report). This is because temperatures are greater and less precipitation falls at lower elevations. The combined plant transpiration and soil evaporation range from 36% to 63% of total AET across the watershed, with only ~35% of this combined amount due to soil evaporation, suggesting plant transpiration is more efficient at removing water from the system than soil evaporation. In addition, sublimation of snow and evaporation of snowmelt water are important components of AET, especially at higher elevations.
Model projections show that AET is driven primarily by temperature, and is therefore likely to increase most for the Tmax scenarios (29% to 58%) and lowest for the Tmin scenarios (10% to 17%; Figure E-9), with highest values in the upper sub-watersheds. This is due to decreased soil infiltration rates and higher precipitation relative to lower areas, which increases evapotranspiration from surface soils. On a seasonal basis, AET is projected to increase by a factor of ~50 during winter (December) compared to negligible change in the spring (TmaxPmax scenario; data not shown). This dramatic increase in AET during former low winter periods is attributed to the significant increase in water available from snowmelt coupled with proportionally warmer winter temperatures.

Figure E-9. Projected percent change in mean annual actual evapotranspiration (AET) for five climate change scenarios relative to the historical baseline by sub-watershed.

Groundwater Recharge and Baseflow to Streams

The hydrologic model calculates either positive or negative groundwater recharge; positive values indicate a net gain in groundwater storage, while negative values indicate a net loss in storage. Simulated basecase average monthly groundwater recharge rates in the Upper Chuitna are positive during May to June and August to September (black outline in upper plot; Figure E-10) in response to infiltration of snowmelt and fall rains, respectively. Simulated recharge is highest in May (more than 550 mm/month), indicating that the historical snowmelt pattern produces a significant spike in recharge to the groundwater system. In all other months, simulated groundwater recharge rates are negative, indicating a decrease in groundwater storage.
In contrast, most scenario climate changes increase the average monthly groundwater recharge (lower plot; Figure E-10). The early seasonal loss of snowpack (Figure E-7) and decrease in soil moisture (Figure E-8) cause a reduction in average monthly recharge during the months of May and June for all scenarios (lower plot; Figure E-10), though recharge in only the Tmin cases remains positive (May). All scenarios in December and January show increased net recharge and positive values, compared to former negative values, which reflected the lack of infiltration during the historical continuous winter snowpack. Nearly all scenarios show an increase in recharge in August through October, indicating that even with increased air temperatures during this period, groundwater recharge increases due to the increased precipitation during this period. Part of this can be explained by the non-linear behavior of soil hydraulic conductivity and soil moisture. Even small increases in soil moisture can cause significant increases in unsaturated zone infiltration and groundwater recharge.

![Figure E-10. Simulated average monthly basecase and scenario recharge (mm/month) for the upper Chuitna sub-watershed (upper plot) and net change in average monthly recharge relative to the basecase (lower plot).](image-url)
Basecase simulations indicate baseflow contributes from 50% to over 90% of streamflow (see Documentation report), with higher percentages in lower sub-watersheds. In upper watershed areas, increased topographic gradients lead to higher percent overland flow contributions to streamflow than from baseflows. The model also suggests that baseflow is higher on uphill sides of watersheds because these areas have higher groundwater gradients towards the stream.

On an annual basis, projected changes in groundwater baseflow into streams are similar to the changes in groundwater recharge (Figure E-11). Once infiltrating water enters the groundwater system, little water is actually lost via evapotranspiration to the atmosphere because depths are generally less than the ~1 meter root depth. As a result, effects of climate change on baseflow are similar to those on recharge. On an annual basis, projected baseflows increase in all sub-watersheds for the Pmax and T50P50 scenarios (8% to 119%). For Pmin cases, baseflows decrease in lower watersheds (to -65%) and increase in upper watersheds (to 12%). This is because recharge and baseflow are more sensitive to AET in lower watersheds. For example, in the basecase 76% of annual precipitation is lost to AET in the Lower Chuitna watershed compared to only 31% in Upper Chuitna.

![Figure E-11](image-url)

**Figure E-11.** Average annual change in baseflow into streams relative to the basecase by sub-watershed.
Change in Overland Flow

In the basecase model simulations, overland flow to streams is generated from cells adjacent to the streams. On a monthly basis, flow has historically been highest during spring melt and fall runoff and lower during other periods (see Documentation Report). Results also show that 10 to 100 times the amount of overland flow is generated in the upper sub-watersheds like the Upper Chuitna and Chuit Creek sub-watersheds than in lower sub-watersheds such as the Lower Chuitna or Stream 2003 (see Documentation Report). This is due to a combination of lower permeability of soils in the upper half of the Chuitna watershed, increased precipitation and steeper topography. Accordingly, the percent of annual precipitation as overland flow to streams ranges from an estimated 1% (lower elevations) to 31% (upper elevations). Simulated average annual overland flow to streams as a percent of total streamflow ranges from 6% (Stream 2003) to 50% (Chuit Creek). In reality, the simulated overland flow percentage in Stream 2003 is likely higher due to a bias in calibrated streamflow attributed to limited accuracy of the topography which prevented explicitly simulating smaller surface water drainages apparent in higher resolution hard-copy topography in mining reports. Increasing grid resolution to less than 200m may also increase the overland flow percentages somewhat as near stream overland areas are better simulated. Despite this, results from the hydrologic model suggest the majority of streamflow are derived from baseflow (groundwater) rather than overland flow (precipitation runoff).

![Figure E-12. Projected percent change in overland flow to streams relative to historical basecase for five climate change scenarios by sub-watershed.](image)
Climate induced changes in overland flow are more sensitive to the changes in precipitation than temperature because they happen relatively quickly compared to subsurface flow processes. Overland flow is projected to increase for Pmax scenarios in all sub-watersheds, and decreases for Pmin scenarios (Figure E-12). The greatest projected increase is for the TminPmax scenario (471%). This indicates that when enough precipitation is added to the system (i.e., Pmax), both overland flow and baseflow increase, and when too little is added (Pmin), even the smaller increases in temperature cause decreases in both of these. The T50P50 scenario projects overland flow most similar to current conditions.

The relative change in overland flow is amplified in lower sub-watersheds because flows are low and therefore more sensitive to changes in AET compared to flows in upper areas (Figure E-12). As a result, even small changes in climate can lead to larger relative impacts on overland flow compared to higher elevations. On a monthly basis, overland flows are projected to increase during fall and winter months (November through April), but decline from May through July due to the earlier melt-out (see Documentation report).

**Changes in Streamflow**

Current seasonal streamflow characteristics of the Chuitna watershed are similar to other non-glacial Alaska watersheds. Generally, flows peak during late-spring/early-summer snowmelt and late-summer/early-fall rains, and slowly recede (several weeks to months) leading up to these periods. The rise in streamflow is relatively quick relative to its decline, which increasingly becomes dominated by groundwater baseflow. Despite the sub-freezing air temperatures and continuous snowpack during winter months that virtually eliminate surface runoff, warmer groundwater continuously discharges to streams.

On an annual basis, significant changes in average streamflow are predicted for the five climate change scenarios (Figure E-13). When precipitation increases significantly (Pmax), annual streamflow averages are predicted to be greater than the historical basecase. When increases in precipitation are minimal or moderate (Pmin or P50), streamflow is projected to remain similar to or decrease relative to the basecase. These projected responses are similar to the responses in baseflow (Figure E-11) and overland flow (Figure E-12).

Seasonally, the model projects that winter streamflow may increase between 100% to 300% and summer streamflow may decrease by 5% to 60% for all climate change scenarios (Figure E-14). This dramatic increase in winter streamflow is caused by greater winter precipitation and the shift towards earlier and greater snowmelt during winter (Figure E-7). Summer decreases are primarily a result of increased AET due to the increase in air temperatures (Figure E-9). However in fall, streamflow is projected to increase relative to the basecase when precipitation is sufficient (Pmax) to offset temperature induced increases in AET, and may remain similar to historical conditions or decrease when insufficient (P50 and Pmin) to overcome increased AET. Spring streamflow decreases for all but the TminPmax scenario, suggesting that only with significant increases in precipitation will sufficient water be available to offset the decrease in spring runoff due to warmer winter temperatures.
In addition to annual and seasonal variation in the magnitude and direction of changes for the five climate scenarios, there are also differences in responses at the sub-watershed level (Figure E-15). For example, simulated winter flows generally increase significantly in the upper sub-watersheds (i.e., Chuit Creek and Upper Chuitna), and decrease for Stream 2003 and the Lone Creek sub-watersheds. Summer streamflow is projected to decrease for all sub-watersheds and scenarios except one (Lone Creek shows a slight increase for the TminPmax scenario). Spring dynamics at the sub-watershed level are highly variable, reflecting the balance between timing and magnitude of winter melt and spring precipitation inputs. In fall, variability appears to be related to the balance of precipitation inputs with higher temperature driven rates of AET.

![Figure E-13. Projected annual changes in streamflow for five climate change scenarios relative to historical basecase. Values are annual means with standard error bars for nine flow gauges within the Chuitna watershed.](image-url)
Figure E-14. Projected seasonal changes in streamflow for five climate change scenarios relative to historical basecase. Values are seasonal means for nine flow gauges within the Chuitna watershed.
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<td>-53%</td>
<td>22%</td>
<td><strong>T50P50</strong></td>
<td>378%</td>
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<td>-54%</td>
<td>18%</td>
</tr>
</tbody>
</table>

**Lower Chuitna**

<table>
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<tr>
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<th>winter</th>
<th>spring</th>
<th>summer</th>
<th>fall</th>
<th></th>
<th>winter</th>
<th>spring</th>
<th>summer</th>
<th>fall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TmaxPmax</strong></td>
<td>363%</td>
<td>-37%</td>
<td>-43%</td>
<td>26%</td>
<td><strong>TmaxPmax</strong></td>
<td>417%</td>
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<td>35%</td>
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<tr>
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<tr>
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<td><strong>T50P50</strong></td>
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<td>-52%</td>
<td>16%</td>
</tr>
</tbody>
</table>

Figure E-15. Simulated average seasonal change in streamflow relative to the basecase by sub-watershed for five climate change scenarios. Green shades indicate an increase in streamflow, while red shades indicate a decrease.
MODEL LIMITATIONS AND FUTURE APPLICATIONS

Although a reasonable calibration of the integrated hydrologic model to available data was accomplished in this study, uncertainties in climate data, model structure (i.e., geologic framework, aquifers etc.), parameter values and conceptualization of flows across the entire Chuitna watershed are significant and affect the accuracy of the calibration and future predictions. Detailed geologic and hydrologic information collected for the company seeking mining permits was unavailable for public use or only available in summarized form, limiting the development of the numerical flow model. We also found some climatic, geologic and hydrologic data essential to understanding the hydrologic system of the watershed have not been collected. Finally, the long run-times and complexity of the fully integrated model did not permit performing a detailed uncertainty analysis. Nevertheless, results are believed to be reasonable for purpose of estimating approximate flow conditions within the historical system and future changes in flows within the system for the range of specified climate changes.

The integrated surface and groundwater model used in this study has helped elucidate the linkages between climate and hydrology in the Chuitna watershed. The hydrologic system responded to even the minimum climate change scenario with significant changes in many key variables, including streamflow. These results should be indicative of how other non-glacial watersheds with similar hydrology in the region would respond to climate change, although the magnitude of change is likely to vary. Future work will include understanding climate change impacts on stream temperature and linking temperature and changes in flow with impacts to salmon habitat.

ACKNOWLEDGEMENTS

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